DOCUMENT RESUME

ED 033 866 SE 007 675

AUTHOR Montgomery, Jerry L.
TITLE A Comparison of BSCS Versus Traditional Teaching Methods by Testing Student Achievement and Retention of Biology Concepts.
INSTITUTION Ball State Univ., Muncie, Ind.
Pub Date May 69
Note 65p.

EDRS Price EDRS Price MF-$0.50 HC-$3.35
Descriptors *Academic Achievement, Biology, *Comparative Analysis, Conventional Instruction, *Course Evaluation, Inquiry Training, *Retention Studies, Science Course Improvement Project, Secondary School Science, *Teaching Methods
Identifiers Biological Sciences Curriculum Study, Nelson Biology Test, Processes of Science

Abstract

The purpose of this study was to examine the effect of the Biological Sciences Curriculum Study (BSCS) materials and the inquiry teaching method on student achievement and retention in biology. Teachers were selected who used BSCS materials with inquiry methods, BSCS materials with traditional methods, traditional materials with inquiry methods, and traditional materials with traditional methods. Twelve students selected at random from the classes of each teacher chosen were pre-tested and post-tested using The Nelson Biology Test and The Processes of Science Test as a measure of achievement, then the same tests were administered after the summer vacation as a measure of retention. The data were analyzed by analysis of coveriance using the pretest scores as covariates in analyzing the post-test scores, and the post-test scores as covariates in analyzing the retention scores. The results indicated that the BSCS students taught by inquiry methods showed the greatest achievement, all BSCS students showed greater retention, inquiry taught traditional students showed greater retention on the Processes of Science Test than traditionally taught traditional students, and tenth grade students out-performed ninth grade students. An unexpected finding was a positive relationship between class size and both achievement and retention. (EB)

# A COMPARISON OF BSCS VERSUS TRADITIONAL TEACHING METHODS BY TESTING STUDENT ACHIEVEMENT AND RETENTION OF BIOLOGY CONCEPTS

A REPORT

SUBMITTED TO THE

EAST CENTRAL INDIANA

CURRICULUM IMPROVEMENT PROJECT

by

JERRY L. MONTGOMERY



BALL STATE UNIVERSITY

MUNCIE, INDIANA

MAY, 1969

TABLE OF CONTENTS

## PREFACE

This paper is the final report to the school personnel who participated in this study. It is hoped that the administrators and teachers who read this report will find it informative and useful in helping to implement curriculum change.

It should be pointed out that the conclusions drawn are tentative. It is difficult to estimate the effects of all the variables that may have contributed to the results shown. However, the results do indicate that teachers and administrators need to look carefully at their situation to determine if they should adopt one of the three BSCS text versions. The schools which are currently using the BSCS materials no longer need to be defensive of that fact.

Inquiry as a teaching technique needs more exploration, but this research indicates that there is little likelihood of harm to students if inquiry is used. If BSCS materials are used it only makes good sense to adopt the BSCS philosophy of teaching by the inquiry method. It also appears likely that teachers have not yet approached the upper limits in the use of inquiry. In other words, the teachers who are using inquiry methods presently should try to expand its use in their classes, and teachers who are not using inquiry procedures should at least give it a fair trial.

Such errors as might occur in this paper are the responsibility of the writer and his alone. Many people, however, contributed to the conduct and completion of the research and the writer would like to express his appreciation to all of them. Special thanks are due to the administrators, guidance counselors, teachers, and students who were intimately involved with the conduction of the research. The writer is grateful to his major advisor, Dr. F. Leon Bernhardt, his doctoral committee, and Dr. Jerry J. Nisbet for their support and encouragement.

## LIST OF TABLES

LIST OF FIGURES

# I. PROBLEM

## A. Statement of Problem

In January, 1959, the American Institute of Biological Sciences (AIBS) established the Biological Sciences Curriculum Study (BSCS) Committee as a means of contributing to the improvement of secondary school education in the field of biology. The BSCS Committee was supported financially by the National Science Foundation. A result of this committee's work was the production of a variety of curriculum materials, much of which has been widely adopted by secondary schools during the past few years. The three textbook versions and accompanying laboratory manuals were probably the most important and most widely adopted. In addition to the materials produced, many writers associated with BSCS advocated a change in teaching style away from the authoritative mode and toward the mode of inquiry.

It was the contention of the BSCS Committee that the new materials and the new teaching style would result in greater achievement and retention than the so-called traditional approaches. The purpose of this study was to test that contention. The problem then became one of selecting schools and teachers using the BSCS materials and matching them with schools and teachers using the more traditional materials. Within each of these groups the problem was to determine which teachers were using the inquiry mode of teaching and to what degree. The next part of the

problem was to compare the achievement and retention of these groups on standardized tests. Another aspect of the problem was to control as closely as possible any other variable that might contribute to achievement or retention of biological subject matter.

B. Significance of Problem

Many schools have adopted the BSCS materials for use in their general biology classes without fully understanding the difference between this material and the traditional materials they had previously used. In some instances teachers have not had adequate background in the updated subject material contained in the BSCS texts. The BSCS materials have placed an emphasis on laboratory work with living organisms, and some schools which have adopted these materials have not had adequate laboratory facilities to meet these laboratory needs. Perhaps even more significantly many administrators and teachers, who have adopted the BSCS materials, have not understood the BSCS philosophy that science learning should be by the mode of inquiry. The results of this research should help administrators and teachers decide whether or not they wish to adopt the BSCS materials.

At the time of this writing there had been no published reports, to this writer's knowledge, of student retention of biology facts and concepts. It had been the contention of several of the science educators, writing about BSCS materials, that the study of those materials would reduce the loss of biological knowledge and thus increase retention. According to those writers, the decrease in the number of facts contained in the BSCS materials and the increased emphasis on concepts and principles

and learning by inquiry would serve the purpose of increasing retention by biology students. A major purpose of this study was to obtain and examine evidence comparing the preceding contentions.

C. Definition of Terms

To facilitate identification and for ease of reference, certain terms will be used throughout this paper that may not have a uniform meaning to all readers. In this paper these terms will have the meanings noted, rather than the broader or narrower definitions used in other contexts.

Achievement will mean measureable gains on either the Nelson Biology Test or the Processes of Science Test. Retention will refer to scores on either of the above tests as determined by those tests after the students have been out of the biology course for one summer.

Inquiry teaching method will be used to mean that teaching method which allows the student the maximum participation in deciding what and how he will learn. This method is also meant to allow the student to formulate his own hypotheses, to test them in his own way, and to draw his own conclusions. In this way, the student will formulate his own concepts and his own conceptual schemes. There are many implications in this definition which need to be made clear. First, the student will have the freedom to choose within the subject field of biology what concepts he wishes to study. Second, he will be able to move freely around in the classroom to carry out his inquiries. Third, he will be given some time for reflection to determine his conclusions and to formulate his concepts. A fourth implication is that the authoritarian approach will be abandoned and that the classroom will be student centered rather than teacher or text centered.

In addition to the preceding implications, there were two related assumptions which much of the structure of this paper depended upon. One was that there existed a continuum from authoritarian to inquiry method along which teachers and their students could be placed. A second assumption was that the inquiry method could be related to achievement and the retention of biology concepts as identified on standardized tests.

BSCS materials will refer to any publication sponsored by the BSCS Committee, but generally this involves only the texts and the related laboratory manuals.

For identification of the major groups, capital letters will be used and the subgroups will be denoted with a small letter subscript as follows:

BSCS......All students using BSCS biology materials.

$BSCS_i$.....Subgroup of students using BSCS biology materials and being taught by the inquiry method.

$BSCS_t$.....Subgroup of students using BSCS biology materials and being taught by the traditional methods.

$BSCS_{10}$....Subgroup of students in tenth grade BSCS biology.

TL........All students using traditional materials.

$TL_i$.......Subgroup of students using traditional biology and being taught by the inquiry method.

$TL_t$.......Subgroup of students using traditional biology materials and being taught by traditional methods.

$TL_{10}$......Subgroup of students in tenth grade using traditional biology materials.

## D. Hypotheses Tested

Achievement and retention has been measured on two tests, the Nelson Biology Test and the Processes of Science Test. The original hypotheses were that the newer approaches of the BSCS materials and the inquiry teaching method would have a positive effect on both sets of test

scores by students involved with those approaches. The hypotheses to be tested, however, will be stated in the null form to simplify statistical treatment. The null hypotheses were:

1. There will be no significant difference in achievement when the BSCS group is compared with:

   1.1 - TL group on the Nelson Biology post-test.

   1.2 - TL group on the Processes of Science post-test.

   1.3 - TL group on the Nelson Biology retention test.

   1.4 - TL group on the Processes of Science retention test.

2. There will be no significant difference in achievement when the ninth grade students are compared with:

   2.1 - the tenth grade students on the Nelson Biology post-test.

   2.2 - the tenth grade students on the Processes of Science post-test.

   2.3 - the tenth grade students on the Nelson Biology retention test.

   2.4 - the tenth grade students on the Processes of Science retention test.

3. There will be no significant difference in achievement when male students are compared with:

   3.1 - female students on the Nelson Biology post-test.

   3.2 - female students on the Processes of Science post-test.

   3.3 - female students on the Nelson Biology retention test.

   3.4 - female students on the Processes of Science retention test.

4. There will be no significant difference in achievement when the $BSCS_i$ subgroup is compared with:

   4.1 - $BSCS_t$ subgroup on the Nelson Biology post-test.

   4.2 - $BSCS_t$ subgroup on the Processes of Science post-test.

   4.3 - $BSCS_t$ subgroup on the Nelson Biology retention test.

   4.4 - $BSCS_t$ subgroup on the Processes of Science retention test.

5. There will be no significant difference in achievement when the $BSCS_i$ subgroup is compared with:

   5.1 - $TL_i$ subgroup on the Nelson Biology post-test.

   5.2 - $TL_i$ subgroup on the Processes of Science post-test.

   5.3 - $TL_i$ subgroup on the Nelson Biology retention test.

   5.4 - $TL_i$ subgroup on the Processes of Science retention test.

6. There will be no significant difference in achievement when the $BSCS_i$ subgroup is compared with:

   6.1 - $TL_t$ subgroup on the Nelson Biology post-test.

   6.2 - $TL_t$ subgroup on the Processes of Science post-test.

   6.3 - $TL_t$ subgroup on the Nelson Biology retention test.

   6.4 - $TL_t$ subgroup on the Processes of Science retention test.

7. There will be no significant difference in achievement when the $BSCS_t$ subgroup is compared with:

   7.1 - $TL_i$ subgroup on the Nelson Biology post-test.

   7.2 - $TL_i$ subgroup on the Processes of Science post-test.

   7.3 - $TL_i$ subgroup on the Nelson Biology retention test.

   7.4 - $TL_i$ subgroup on the Processes of Science retention test.

8. There will be no significant difference in achievement when the $BSCS_t$ subgroup is compared with:

   8.1 - $TL_t$ subgroup on the Nelson Biology post-test.

   8.2 - $TL_t$ subgroup on the Processes of Science post-test.

   8.3 - $TL_t$ subgroup on the Nelson Biology retention test.

   8.4 - $TL_t$ subgroup on the Processes of Science retention test.

9. There will be no significant difference in achievement when the $TL_i$ subgroup is compared with:

   9.1 - $TL_t$ subgroup on the Nelson Biology post-test.

   9.2 - $TL_t$ subgroup on the Processes of Science post-test.

   9.3 - $TL_t$ subgroup on the Nelson Biology retention test.

   9.4 - $TL_t$ subgroup on the Processes of Science retention test.

## II. REVIEW OF RELATED LITERATURE

### A. BSCS Biology

Books by Seymore Fowler (40), Paul Dehart Hurd (67), and Marshall and Burkman (84) trace the historical origins of biology in the United States and relate BSCS biology to its contemporary setting. Ralph Tyler (119) has identified many of the influences which will shape science teaching in the future.

Bentley Glass (46), Arnold Grobman (51), and Addison Lee (78) describe the three versions of BSCS biology and give the objectives of the BSCS program. Van Deventer (120) has also described the BSCS versions and compared them with traditional texts. Metzner (88) and Brandwein (17) have described and discussed the materials produced by BSCS for gifted students. Addison Lee (79) has discussed the laboratory block program of BSCS.

Many writers, including Grobman (52), Grobman (52), Fordyce (39), Crossland (30), Weishar and Terry (126), Hutto (69), Cornelius (28), and Frankel (42), have praised the BSCS program and have urged its consideration for adoption by administrators and teachers. The preceding writers do not urge the adoption of the BSCS program without first a careful analysis of the materials for their suitability to local conditions.

Goldstein (47) and Ausubel (6) have raised questions about the suitability and relevance of the BSCS program. They particularly question the pedogical approach of the BSCS materials for the non-science major and the academically less talented student.

Hulda Grobman (57), Wienburn Wallace (123), and the Psychological Corporation (115) have discussed the results of the BSCS evaluation program. They found that there were no statistically significant differences in the achievement of BSCS students and traditional students. Lisonbee and Fullerton (82) found no significant differences between BSCS and traditional students on traditional tests, but found that high ability and medium ability students using BSCS materials achieved significantly higher on the BSCS comprehensive final than did like ability students using traditional materials. Retention of biology concepts were not tested in any of these studies.

B. Inquiry and the Teaching of Biology

Many science educators, Davis (31), Grobman (53), Robinson (98), Kochendorfer (75), Belanger (13), Howard (64), Suchman (108, 109, 110, 111, 112), Schwab (103), Brandwein (17), and Rutherford (101) have advocated the use of inquiry in the classroom as the proper way of teaching biology. Bruner (18, 19, 20, 21, 22) has given the psychological and philosophical foundation for the teaching of science by inquiry. Ausubel (7, 8) is highly critical of Bruner and the discovery and inquiry approach to science teaching.

C. Limitations of Previous Studies

The BSCS writers, in conjunction with the Psychological Corporation, have conducted extensive testing programs. These programs were variously aimed at determining how the BSCS materials were meeting the BSCS objectives, developing tests to measure gains in achievement by the students using BSCS materials, and comparing gains in achievement by BSCS students with gains in achievement by students using traditional materials.

The above studies were open to a number of criticisms: (a) they were under the sponsorship of the same people who developed the materials; (b) the materials were new and experimental at the time of testing, thus the "Hawthorne" effect may have been operating; (c) it was assumed that the materials were being taught in the inquiry manner, but this was not substantiated by any classroom observations; and (d) there was no follow-up on these students after they left biology.

Subsequent studies have largely corrected the first of these two criticisms. The inquiry method has been tested in a few studies, but always in a very limited manner involving only three or four teachers usually in a highly controlled experimental situation and generally with teaching materials other than the BSCS biology materials.

This research, then, differs from previous studies in the following ways: (a) it is not sponsored by any group that has a stake in the outcome of the research; (b) the commercial editions of the BSCS materials have been on the market about four years, thus the "Hawthorne" effect should be minimal; (c) this was a field study involving 24 teachers and a random selection of their students; (d) the subgroups were using inquiry as actually practiced under field conditions and not in a tightly controlled and manipulated situation; and (e) there was a follow-up in the form of a retention test after the students left biology.

## III. METHOD OF RESEARCH

### A. Selection of Sample

Most East Central and Northeastern Indiana schools were contacted either by mail or in person. The initial contact was with the school superintendent to whom the research was described and of whom permission was asked to continue with the research. The approval for continuing the research was also requested of the principal and the biology teacher. A total of 100 school districts were contacted. Of these, 68 granted approval, 11 declined to cooperate, and 21 did not reply. Each of the 68 school districts which granted approval for the research returned a general information and permission form upon which further selection was based. Table 1 shows how these schools were distributed among grade levels and type of material used. Also shown in Table 1 is the number of teachers selected.

TABLE 1

ANALYSIS OF 68 SCHOOLS WHICH AGREED TO COOPERATE IN THE RESEARCH

| Type of Material | Grade Level | No. of Schools Replying Favorably | Per Cent of the 68 Favorable Replies | No. of Teachers Selected | Analysis of Data Based on No. of Teachers |
|---|---|---|---|---|---|
| BSCS | 10th | 9 | 13 | 4 | 4 |
| BSCS | 9th | 12 | 18 | 11 | 10 |
| TL | 10th | 8 | 12 | 4 | 4 |
| TL | 9th | 39 | 57 | 11 | 10 |

To select those schools actually to be included in the study, the BSCS and traditional schools were matched as closely as possible on the following factors: (a) size of school, (b) type and size of community, (c) method of selection for general biology students, and (d) semesters of science prior to general biology.

The principals of the schools selected were requested to send the class lists of the teachers who would be involved in the research. The students who were to be tested were then randomly selected, utilizing a table of random numbers, from the class list. Twelve students and two alternates were selected from each teacher to be involved.

An exception to the above procedure occurred in a school system where six teachers were involved. Each of these six teachers were allowed to select an entire class for pre-testing and post-testing for convenience in testing. For the retention tests, a random selection of 12 students of the 6 teachers were tested. The analysis of data was based on only the students completing the retention tests. Therefore, the data treatment for this group was consistent with the rest of the research.

## B. Instruments and Testing Procedures

The Nelson Biology Test was chosen as the instrument needed to test for achievement. The Nelson Biology Test was revised in 1964 and reflects the revised content of traditional courses and the new content of BSCS courses. Also, the Nelson Biology Test has been commonly used in research of this type.

The Processes of Science Test (POST) was chosen to help evaluate the student's ability to use inquiry. The Processes of Science Test was prepared by the BSCS Committee. The test manual stated:

> In preparing POST, the focus was on intellectual history of biology, and science as inquiry. The concerns of the authors were with the methodology of science; the basis for judging facts, principles, and concepts; the extent to which the student had developed standards for judging or appraising data; the student's ability to interpret qualitative and quantitative data; and his ability to screen and judge the design of experiments. The test measures the ability of students to recognize adequate criteria for accepting or rejecting hypotheses, and to evaluate the general structure of experimental design in science, including the need for controls, repeatability, adequate sampling, and careful measurement.

The Nelson Biology Test and the Processes of Science Test were given to each student as a pre-test, post-test and a retention test. The pre-test was given in September and early October, 1967. The post-test was given in April, 1968, and the retention test was given in September, 1968. The tests were administered by the teachers or the guidance counselors in the schools selected. The tests, answer sheets, student list, test instructions, marking pencils, and return postage were mailed to the respective test administrators in each school. After receiving the tests, the test administrator had one week in which to give the tests to the selected biology students.

A third instrument, devised by the researcher, was called an Inquiry Rating Scale. The Inquiry Rating Scale was used by an observer in the classroom to rate teachers in their use of inquiry. The instrument was divided into two major parts, the laboratory and class discussion. The laboratory portion was broken into nine elements and the part on class

discussion was subdivided into twelve elements. In addition, three elements were concerned with the physical environment and one with the use of time in the classroom. The classroom teacher could be rated from one to ten on each element of inquiry with one being low and ten high. The scale moves from the authorative mode to the inquiry mode which permits the student more freedom in deciding what and how he is to learn.

The Inquiry Rating Scale was examined by two professors of education and one professor of biology, concerned with science education, to determine the face validity in determining inquiry. The reliability of the Inquiry Rating Scale was determined by the Pearson-Product Moment Correlation between the first observation and the second observation. That correlation was 0.73. Another check on the reliability of the scale was that another observer and this researcher rated four teachers independently. The result was a rank-order correlation of 1.00 for the teachers between the observer and the researcher. While not enough cases were involved to be statistically significant, the high correlation obtained at least gives an indication of reliability.

Table 2 reports the correlations of the observations in which the Inquiry Rating Scale was used and other factors related to inquiry. The test rating was based on a sample of teacher-made tests collected from each teacher. A science educator and the researcher rated five tests independently and a rank-order correlation of 1.00 was obtained. The composite rating is an average of the two observations using the Inquiry Rating Scale and the test rating. Selection of subgroups was based on the composite rating. The subgroups $BSCS_i$, $BSCS_t$, $TL_i$, and $TL_t$ were all

selected from the ninth grade in order not to bias the comparisons between them by mixing grade levels. Three teachers from each group with the highest composite rating were designated as inquiry subgroups and the three teachers from each group with the lowest composite rating were designated as traditional subgroups.

TABLE 2

CORRELATION OF INQUIRY RATINGS

| Factor | Correlate | N | r[a] |
|---|---|---|---|
| Observation #1 | Observation #2 | 24 | 0.7297[b] |
| Observation #1 | Test Rating | 25 | 0.4757[c] |
| Observation #1 | Composite Rating | 27 | 0.8453[b] |
| Observation #2 | Test Rating | 22 | 0.3087 |
| Observation #2 | Composite Rating | 24 | 0.8058[b] |
| Test Rating | Composite | 25 | 0.8308[b] |
| Composite Rating | Time in Laboratory | 25 | 0.2753 |
| Composite Rating | Teaching Experience | 26 | -0.2147 |
| Composite Rating | NSF Institutes | 26 | -0.0191 |

[a]Pearson-Product Moment correlations calculated on a Wang calculator with an electronic calculator card programmer CP-1.

[b]Significant at 0.001. From Table VI, p. 274, Downie and Heath (34)

[c]Significant at 0.02. Ibid.

C. Background Data

Table 3 presents a summary of the background data gathered about each school. As can be seen from Table 3, the traditional students went to smaller high schools and they generally had poorer laboratory facilities than the BSCS students. The subgroups were widely distributed over the range for community type, school size and adequacy of facilities and no consistent differences were apparent in the data.

TABLE 3

BACKGROUND DATA ON SCHOOLS
FOR EACH GROUP AND SUBGROUP

| Group | Community[a] | | | School Size[b] | | | Facilities[c] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Urban | Suburban | Rural | Large | Medium | Small | Good | Ave. | Poor |
| BSCS | 7 | 1 | 6 | 2 | 11 | 1 | 5 | 7 | 2 |
| TL | 7 | 1 | 6 | 1 | 8 | 5 | 1 | 9 | 4 |
| $BSCS_i$ | 2 | 0 | 1 | 1 | 2 | 0 | 0 | 2 | 1 |
| $BSCS_t$ | 2 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 |
| $BSCS_{10th}$ | 1 | 0 | 3 | 1 | 3 | 0 | 3 | 1 | 0 |
| $TL_i$ | 1 | 0 | 2 | 0 | 1 | 2 | 0 | 3 | 0 |
| $TL_t$ | 2 | 0 | 1 | 0 | 3 | 0 | 0 | 3 | 0 |
| $TL_{10th}$ | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 2 |

[a]Communities were classified as follows: over 80,000-urban; from 10,000 to 80,000-suburban; less than 10,000-rural.

[b]School size based on enrollment: large-over 1,000; medium-from 500 to 1,000; small-up to 500.

[c]Facilities were judged in relation to ability to do laboratory work recommended by BSCS: Good-more than adequate; Average-barely adequate; Poor-not adequate for more than dissection and limited microscopic work.

Since the students were selected from a teacher and subgrouping was based on the teaching technique which the teacher followed, the basis for grouping was the teacher. Table 4 lists the background information gathered on each teacher and a summary of that data for each subgroup.

As can be seen in Table 4, on most facts other than the inquiry factors (Columns 2, 3, 4, and 5), the subgroups were not greatly different. It would appear that the high inquiry groups ($BSCS_i$, $BSCS_{10th}$, and $TL_i$) generally had more quarter hours of science and fewer quarter hours of education than the low inquiry groups ($BSCS_t$, $TL_t$, $TL_{10th}$). None of the teachers in the $TL_t$ subgroup majored in biology, while all but one of the teachers in the remaining subgroups did major in biology.

TABLE 4

TEACHER BACKGROUND INFORMATION ON SUBGROUPS

| Group | Code | S | I1 | I2 | TR | IC | QB | QS | QE | N | B | Y | D | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $BSCS_i$ | 201 | M | 23 | 22 | 59 | 35 | 80 | 80 | 40 | 1 | 1 | 7 | M.A. | 0 |
| | 221 | F | 45 | 33 | 59 | 46 | 106 | 56 | 24 | 0 | 0 | 2 | B.S. | X |
| | 281 | M | 37 | 47 | 30 | 38 | 67 | 107 | — | 5 | 0 | 16 | M.A. | X |
| | Mean* | | 35 | 34 | 49 | 40 | 84 | 81 | 32 | 2 | 0 | 8 | | |
| $BSCS_t$ | 131 | M | 21 | — | 17 | 19 | 90 | 51 | 29 | 1 | 1 | 6 | M.A. | X |
| | 141 | F | 33 | 16 | 01 | 17 | 64 | 63 | 28 | 4 | 0 | 8 | M.A. | X |
| | 211 | M | 27 | 21 | 10 | 19 | 44 | 32 | 99 | 2 | 2 | 10 | M.A. | X |
| | Mean* | | 27 | 19 | 09 | 18 | 66 | 49 | 52 | 2 | 1 | 8 | | |
| $BSCS_{10}$ | 021 | M | 35 | 33 | 41 | 36 | 78 | 27 | 24 | 0 | 0 | 3 | M.A. | X |
| | 061 | F | 39 | 44 | 33 | 39 | 72 | 69 | 33 | 0 | 0 | 5 | B.S. | X |
| | 161 | M | 26 | — | 39 | 32 | 89 | 60 | 85 | 3 | 0 | 9 | M.A. | X |
| | 231 | M | 32 | 53 | 22 | 36 | 77 | 80 | 48 | 5 | 0 | 15 | M.A. | X |
| | Mean* | | 33 | 43 | 34 | 37 | 79 | 59 | 48 | 2 | 0 | 8 | | |
| $TL_i$ | 011 | F | 45 | 60 | — | 53 | 72 | 30 | 54 | 2 | 1 | 7 | M.A. | X |
| | 051 | M | 46 | 44 | 18 | 36 | 104 | 53 | 31 | 0 | 0 | 2 | B.S. | X |
| | 271 | F | 49 | 50 | 38 | 46 | 80 | 49 | 38 | 0 | 0 | 3 | B.S. | X |
| | Mean* | | 47 | 51 | 19 | 45 | 85 | 44 | 41 | 1 | 0 | 4 | | |
| $TL_t$ | 042 | M | 17 | 21 | 01 | 13 | 60 | 57 | — | 1 | 0 | 19 | M.A. | 0 |
| | 171 | M | 20 | 25 | 07 | 17 | 33 | 07 | 173 | 0 | 0 | 2 | B.S. | 0 |
| | 272 | M | 14 | 18 | 18 | 17 | 50 | 120 | 170 | 0 | 0 | 13 | M.A. | 0 |
| | Mean* | | 17 | 21 | 09 | 16 | 48 | 61 | 172 | 0 | 0 | 11 | | |
| $TL_{10}$ | 091 | M | 19 | 24 | 15 | 19 | 61 | 12 | 53 | 0 | 0 | 4 | B.S. | X |
| | 101 | M | 20 | 30 | 18 | 23 | 89 | 85 | 62 | 0 | 0 | 21 | M.A. | X |
| | 111 | M | 29 | 26 | 31 | 29 | 105 | 40 | — | 0 | 0 | 1 | M.A. | X |
| | 151 | M | 17 | 20 | 08 | 15 | 89 | 05 | 21 | 0 | 0 | 5 | B.S. | X |
| | Mean* | | 21 | 25 | 18 | 22 | 86 | 36 | 45 | 0 | 0 | 8 | | |

S=Sex of Student
I1=Inquiry Rating #1
I2=Inquiry Rating #2
TR=Test Rating
IC=Inquiry Composite
QB=Qtr. Hrs. Biology
QS=Qtr. Hrs. Science
QE=Qtr. Hrs. Education
N=NSF Institutes
B=BSCS Institutes
Y=Yrs. Teaching Experience
D=Degree; M.A., Master's Degree, B.S., Bachelor's Degree
M=Major in Biology; an "X" indicates a major in biology.
*Mean rounded to nearest whole number

Table 5 compared the major groups on the factors listed in Table 4. As shown in the table, the BSCS teachers had slightly more science than the TL teachers, but the TL teachers averaged 30 more quarter hours in education courses than the BSCS teachers. The BSCS teacher had more often attended a National Science Foundation Institute than the traditional teacher. The TL teacher had almost four years more teaching experience than the BSCS teacher.

TABLE 5

SUMMARY OF TEACHER BACKGROUND

| Item | BSCS | TL |
|---|---|---|
| 1. Males | 11[a] | 12[a] |
| Females | 3[a] | 2[a] |
| 2. Inquiry Rating #1 | 31.4 | 26.1 |
| 3. Inquiry Rating #2 | 31.8 | 30.0 |
| 4. Test Rating | 27.9 | 15.9 |
| 5. Inquiry Composite | 29.8 | 25.4 |
| 6. Quarter Hours Biology | 77.4 | 72.8 |
| 7. Other Science | 52.2 | 44.6 |
| 8. Education | 41.2 | 71.6 |
| 9. NSF Institutes | 24[a] | 6[a] |
| 10. BSCS Institutes | 6[a] | 4[a] |
| 11. Years of Experience | 7.5 | 11.1 |
| 12. Master's Degree | 9[a] | 8[a] |
| Bachelor's Degree | 3[a] | 6[a] |
| 13. Major in Biology | 10[a] | 10[a] |

[a]These represent the total numbers for the group; all other figures are means.

Table 6 indicates the background of the students in the various groups. The $TL_i$ students have had the poorest background in science of any group. The BSCS Yellow Version (23) was the most popular text with the BSCS group, and Modern Biology (95) was the most popular text with the TL groups.

TABLE 6

STUDENT BACKGROUND

| Group | Semesters of Previous Science | Text[a] |
|---|---|---|
| BSCS | 3.0 | 8 YV, 4 BV, 2 GV |
| TL | 2.8 | 12 MB, 1 W, 1 GG |
| $BSCS_i$ | 3.0 | 1 YV, 1 BV, 1 GV |
| $BSCS_t$ | 3.0 | 1 YV, 1 BV, 1 GV |
| $BSCS_{10th}$ | 3.0 | 4 YV |
| $TL_i$ | 2.3 | 3 MB |
| $TL_t$ | 3.0 | 2 MB, 1 GG |
| $TL_{10th}$ | 3.0 | 3 MB, 1 W |

[a]YV=Yellow Version; BSCS (23). BV=Blue Version, BSCS (24); GV=Green Version, BSCS (25); MB=Modern Biology (95); W=Weinburg (125); GG=Gregory and Goldman (50).

D. Statistical Treatment

Analysis of covariance was used to compare the groups and the subgroups. The Nelson Test and the Processes of Science Test were compared separately. The pre-tests were used as the covariants with the post-tests and the post-tests were used as the covariants with the retention tests. After first using the pre-tests alone as covariants, the class size was used as an additional covariant. Class size was also used as an additional covariant with the post-tests. The groups and subgroups were divided into male and female students to determine if there were a significant difference in performance between the sexes. The level of significance chosen was 0.05. The computer program used was BMDO5V, General Linear Hypothesis, developed by the Health Science Computing Facility at the University of California at Los Angeles. The computer used was located at Indiana University, Bloomington, Indiana.

Essentially the computer program determined the correlation of the covariate with the test score that was being compared. The test score means were then adjusted on the basis of that correlation. In effect this removes differences in starting points among the groups being compared. The computer did not print out the adjusted means, thus they cannot be reported.

## IV. RESEARCH FINDINGS

### A. Presentation of Data

Tables 7 through 14 report the results from the pre-, post- and retention tests from both the Nelson Biology Test and the Processes of Science Test. Results of the analysis of covariance comparing the various groups and subgroups are also reported.

Table 7 shows the number of students in each group by sex and treatment. The first covariate reported in Table 7 is the result of the Nelson Biology pre-test which was used as the lone covariate in the first comparison and the second covariate is the mean of the class size for each group and subgroup. The standard deviation and the mean of the Nelson Biology post-test are included in Table 7. The mean change shown in Table 7 is the difference between the pre- and post-tests. The total change is determined by multiplying mean change times the number of students in the sample.

Table 8 reports the analysis of covariance on the Nelson Biology post-test. The first column shows the comparisons which were made. The second column shows the difference in the means of the groups compared. If the second mentioned group of a comparison had a higher mean than the first group, the difference is preceded by a negative sign.

A significant F-test indicates that the group with the higher mean has achieved significantly more on the Nelson Biology post-test than the group with the lower mean. The difference in class size is determined in

the same fashion as the difference in mean. The second F-test given for each comparison is based on the use of class size as an additional covariate. The difference shown in the two F-tests is due to any correlation between class size and scores on the Nelson Biology pre-tests. Thus, if a positive correlation exists between class size and score, the F-test will be adjusted in favor of the smaller classes. A positive correlation would exist if the larger classes scored higher on the tests than the smaller classes. For example, in Table 8, the comparison of BSCS and TL shows that the average class size of the BSCS group was 0.62 larger than the average class size of the TL group. Since the mean gain of the TL group was higher than the mean gain of the BSCS group, the first F-test shown in Table 8 favors the TL group. In this instance a positive correlation exists between class size and score; thus, the second F-test has been adjusted in favor of the TL group, the group with the smaller classes. The class sizes for each group are given in Table 7 as the second covariate.

TABLE 7

NELSON BIOLOGY TEST DATA FROM POST-TEST

| Group | Sex | No. | Covar.[a] Mean | Covar.[b] Mean | Std. Dev. | Mean[c] | Mean[d] Change | Total[e] Change |
|---|---|---|---|---|---|---|---|---|
| BSCS | M | 51 | 22.45 | 26.92 | 10.86 | 31.22 | 8.77 | 444.27 |
| BSCS | F | 67 | 18.64 | 26.19 | 9.23 | 26.81 | 8.17 | 547.39 |
| $BS_{10th}$ | M | 25 | 26.88 | 26.88 | 8.07 | 35.00 | 8.12 | 213.00 |
| $BS_{10th}$ | F | 15 | 25.20 | 25.80 | 9.91 | 33.87 | 8.67 | 130.05 |
| TL | M | 44 | 21.57 | 25.30 | 11.37 | 29.30 | 7.73 | 340.12 |
| TL | F | 56 | 22.70 | 27.32 | 10.33 | 32.02 | 9.32 | 521.92 |
| $TL_{10th}$ | M | 28 | 24.79 | 23.88 | 10.11 | 34.46 | 9.67 | 270.76 |
| $TL_{10th}$ | F | 17 | 22.06 | 25.94 | 8.20 | 34.59 | 12.53 | 213.01 |
| $BSCS_i$ | M | 15 | 22.93 | 24.47 | 12.35 | 34.60 | 11.67 | 175.05 |
| $BSCS_i$ | F | 20 | 21.40 | 25.00 | 9.16 | 32.10 | 10.70 | 214.00 |
| $BSCS_t$ | M | 16 | 21.56 | 32.81 | 7.21 | 28.50 | 6.94 | 111.04 |
| $BSCS_t$ | F | 17 | 19.65 | 30.59 | 7.80 | 27.35 | 7.70 | 130.90 |
| $TL_i$ | M | 10 | 19.80 | 22.20 | 8.79 | 27.00 | 7.20 | 72.00 |
| $TL_i$ | F | 18 | 20.00 | 26.17 | 9.24 | 27.83 | 7.83 | 140.94 |
| $TL_t$ | M | 12 | 20.83 | 31.50 | 10.16 | 28.25 | 7.42 | 89.04 |
| $TL_t$ | F | 22 | 23.91 | 30.27 | 9.02 | 34.95 | 11.04 | 242.88 |

[a]The covariate was the Nelson Biology pre-test.

[b]The covariate was the class size.

[c]Mean of the Nelson Biology post-test.

[d]The difference between the first covariate and the Nelson Biology post-test.

[e]Mean change times the number of students.

As shown in Table 8 tnere were no significant differences found between the BSCS students and traditional students on the Nelson Biology post-test. The tenth grade biology students achieved significantly more on this test than did the ninth grade biology students. The difference remained after class size was considered. There was no significant difference found between males and females on the Nelson Biology post-test. For the first three comparisons an F-test of 3.89 would indicate a statistically significant difference at the 0.95 level of confidence. Table 8 indicates that there was a significant difference between the $BSCS_i$ subgroup and the $BSCS_t$ subgroup favoring the $BSCS_i$. The $BSCS_i$ subgroup also scored significantly higher than the $TL_i$ subgroup on the Nelson Biology post-test. In both cases the differences remained after class size was used as an additional covariate. An F-test of 4.02 or higher indicated a statistically significant difference between subgroups. As Table 8 shows, there were no further significant differences found between subgroups on the Nelson Biology post-test.

TABLE 8

RESULTS OF ANALYSIS OF COVARIANCE: NELSON BIOLOGY POST-TEST

| Comparisons | Mean Difference[a] | D.F. | F-Test | Difference in Class Size[b] | F-Test[c] |
|---|---|---|---|---|---|
| BSCS vs TL | -0.82 | 1, 294 | 2.65 | 0.62 | 2.76 |
| 9th vs 10th | -1.21 | 1, 294 | 3.97* | 0.96 | 4.12* |
| M vs F | -0.52 | 1, 294 | 1.20 | -0.68 | 1.12 |
| $BSCS_i$ vs $BSCS_t$ | 3.79 | 1, 63 | 6.37* | -6.90 | 4.33* |
| $BSCS_i$ vs $TL_i$ | 3.51 | 1, 58 | 4.73* | 0.02 | 4.44* |
| $BSCS_i$ vs $TL_t$ | 1.36 | 1, 64 | 1.33 | -5.93 | 0.61 |
| $BSCS_t$ vs $TL_i$ | -0.28 | 1, 56 | 0.00 | 6.92 | 0.36 |
| $BSCS_t$ vs $TL_t$ | -2.43 | 1, 62 | 2.49 | 0.97 | 2.49 |
| $TL_i$ vs $TL_t$ | -2.15 | 1, 57 | 1.88 | -5.95 | 0.44 |

[a]Mean change of the first group minus mean change of second group.

[b]Average class size of the first group minus average class size of the second group.

[c]In addition to the pre-test, class size was used as a covariate.

*Significant at the 0.05 level.

Tables 9 and 10 correspond to Tables 7 and 8 except that the first covariate is the Nelson Biology post-test and the mean is for the Nelson Biology retention test. Figures I, II, and III compare the raw means on the Nelson pre-, post- and retention tests between BSCS and TL, ninth and tenth grades, and males and females, respectively. Figure IV graphs the raw scores on the Nelson Biology pre-, post- and retention tests for the subgroups so that they may be intercompared. It should be emphasized that the figures are the graphs of raw scores and the tables report changes in scores. Thus, in Table 10, the BSCS group shows a change in score from the post-test to the retention test of 1.01 points higher than the TL group, yet Figure I shows that the mean raw score for the BSCS group on the retention test is lower than the mean raw score of the TL group on the Nelson Biology retention test. The actual points on the graphs are not important, but the slope and direction of the line are the important considerations.

TABLE 9

NELSON BIOLOGY TEST DATA FROM RETENTION TEST

| Group | Sex | No. | Covar.[a] Mean | Covar.[b] Mean | Std. Dev. | Mean[c] | Mean[d] Change | Total[e] Change |
|---|---|---|---|---|---|---|---|---|
| BSCS | M | 51 | 31.22 | 26.92 | 13.36 | 31.08 | -0.14 | -7.14 |
| BSCS | F | 67 | 26.81 | 26.19 | 11.30 | 26.81 | 0.00 | 0.00 |
| $BS_{10th}$ | M | 25 | 35.00 | 26.88 | 9.58 | 37.48 | 2.48 | 62.00 |
| $BS_{10th}$ | F | 15 | 33.87 | 25.80 | 12.40 | 36.00 | 2.13 | 31.95 |
| TL | M | 44 | 29.30 | 25.30 | 12.88 | 29.98 | 0.68 | 29.92 |
| TL | F | 56 | 32.02 | 27.32 | 12.49 | 31.11 | -0.91 | -50.96 |
| $TL_{10th}$ | M | 28 | 34.46 | 23.88 | 12.18 | 33.46 | -1.00 | -28.00 |
| $TL_{10th}$ | F | 17 | 34.59 | 25.94 | 8.61 | 33.59 | -1.00 | -17.00 |
| $BSCS_i$ | M | 15 | 34.60 | 24.47 | 14.75 | 35.00 | 0.40 | 6.00 |
| $BSCS_i$ | F | 20 | 32.10 | 25.00 | 7.92 | 33.95 | 1.85 | 34.00 |
| $BSCS_t$ | M | 16 | 28.50 | 32.81 | 9.09 | 29.94 | 1.44 | 23.04 |
| $BSCS_t$ | F | 17 | 27.35 | 30.59 | 9.08 | 28.47 | 1.12 | 19.04 |
| $TL_i$ | M | 10 | 27.00 | 22.20 | 9.81 | 23.80 | -3.20 | -32.00 |
| $TL_i$ | F | 18 | 27.83 | 26.17 | 11.80 | 27.39 | 0.44 | 7.92 |
| $TL_t$ | M | 12 | 28.25 | 31.50 | 12.91 | 28.25 | 0.00 | 0.00 |
| $TL_t$ | F | 22 | 34.95 | 30.27 | 11.46 | 32.05 | 2.90 | 63.80 |

[a]The covariate was the Nelson Biology pre-test.

[b]The covariate was the class size.

[c]Mean of the Nelson Biology retention test.

[d]The difference between the first covariate and the Nelson Biology post-test.

[e]Mean change times the number of students.

TABLE 10

RESULTS OF ANALYSIS OF COVARIANCE: NELSON BIOLOGY RETENTION TEST

| Comparisons | Average Mean Difference[a] | D.F. | F-Test | Difference in Class Size[b] | F-Test[c] |
|---|---|---|---|---|---|
| BSCS vs TL | 1.01 | 1, 294 | 3.89* | 0.62 | 3.32 |
| 9th vs 10th | -1.76 | 1, 294 | 0.66 | 0.96 | 0.99 |
| Male vs Female | 0.62 | 1, 294 | 0.27 | -0.68 | 0.40 |
| $BSCS_i$ vs $BSCS_t$ | -0.05 | 1, 63 | 0.24 | -6.90 | 1.10 |
| $BSCS_i$ vs $TL_i$ | 2.08 | 1, 58 | 3.64 | 0.02 | 3.46 |
| $BSCS_i$ vs $TL_t$ | -0.66 | 1, 64 | 2.31 | -5.93 | 3.23 |
| $BSCS_t$ vs $TL_t$ | 2.13 | 1. 56 | 3.99 | 6.92 | 0.34 |
| $BSCS_t$ vs $TL_t$ | -0.61 | 1, 62 | 2.54 | 0.97 | 2.27 |
| $TL_i$ vs $TL_t$ | -1.02 | 1, 57 | 0.00 | -5.95 | 0.92 |

[a]Mean change of the first group minus mean change of second group.

[b]Average class size of the first group minus average class size of the second group.

[c]In addition to the pre-test, class size was used as a covariate.

*Significant at the 0.05 level.

In Table 10 only one statistically significant difference is shown. The BSCS group achieved significantly higher on the Nelson Biology retention test than did the TL group. After class size was considered as a covariate that difference disappeared. In Figure I, where the raw scores of these two groups are graphed, it can be seen that the slope of the BSCS line from post- to retention test is positive while the corresponding slope of the TL line is negative.

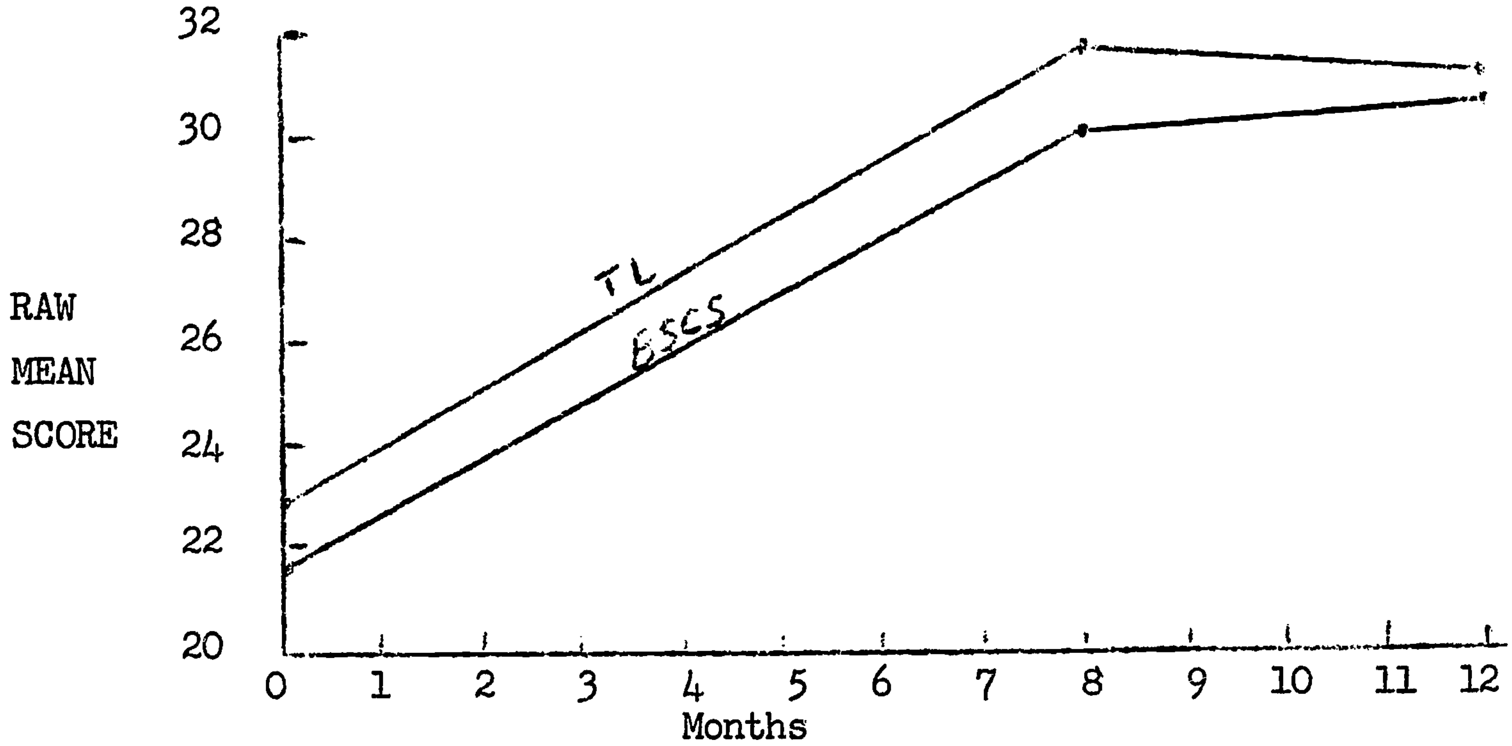


Figure I. - Nelson Biology Test: BSCS vs. TL

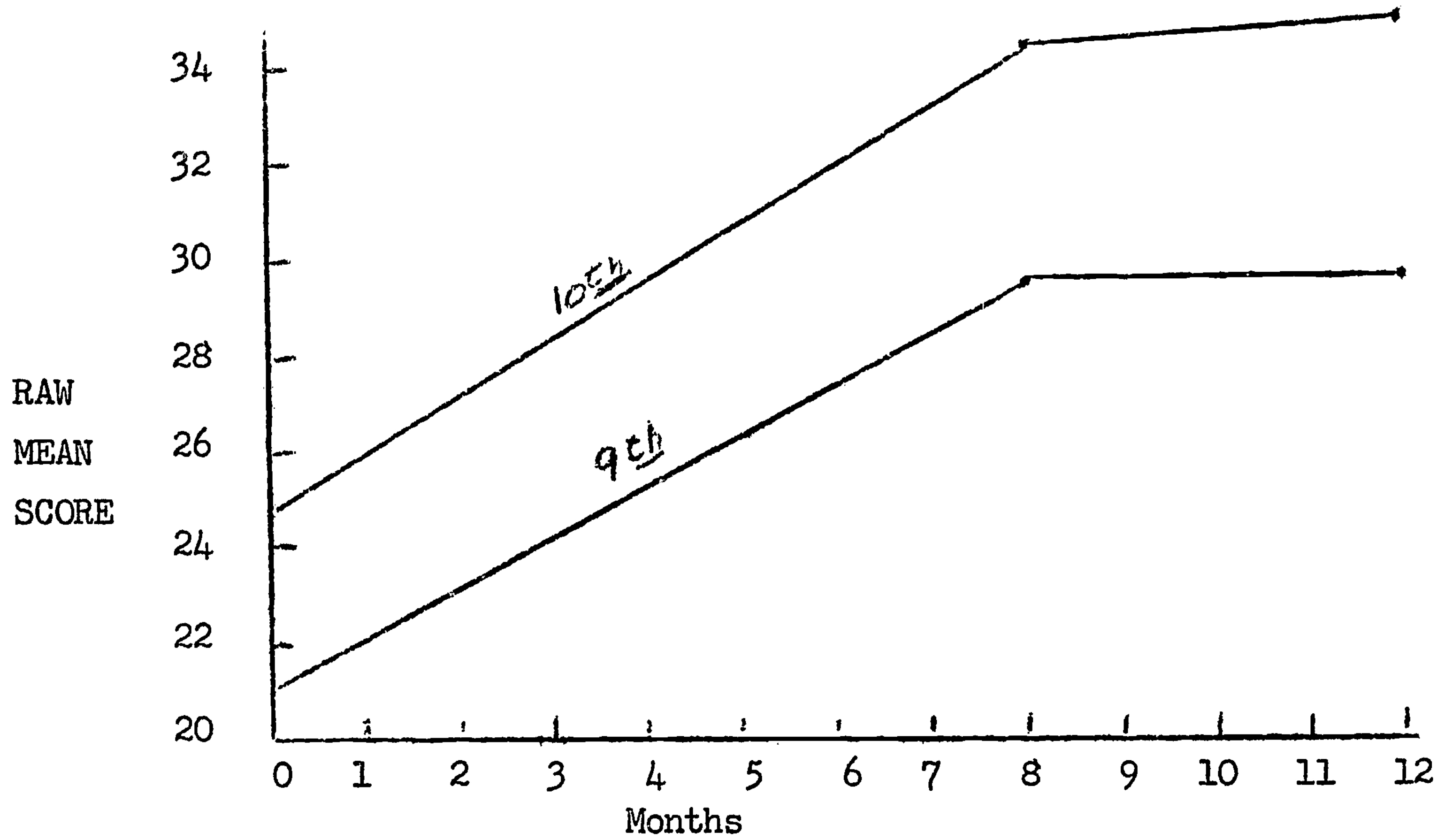


Figure II. - Nelson Biology Test: 9th vs. 10th.

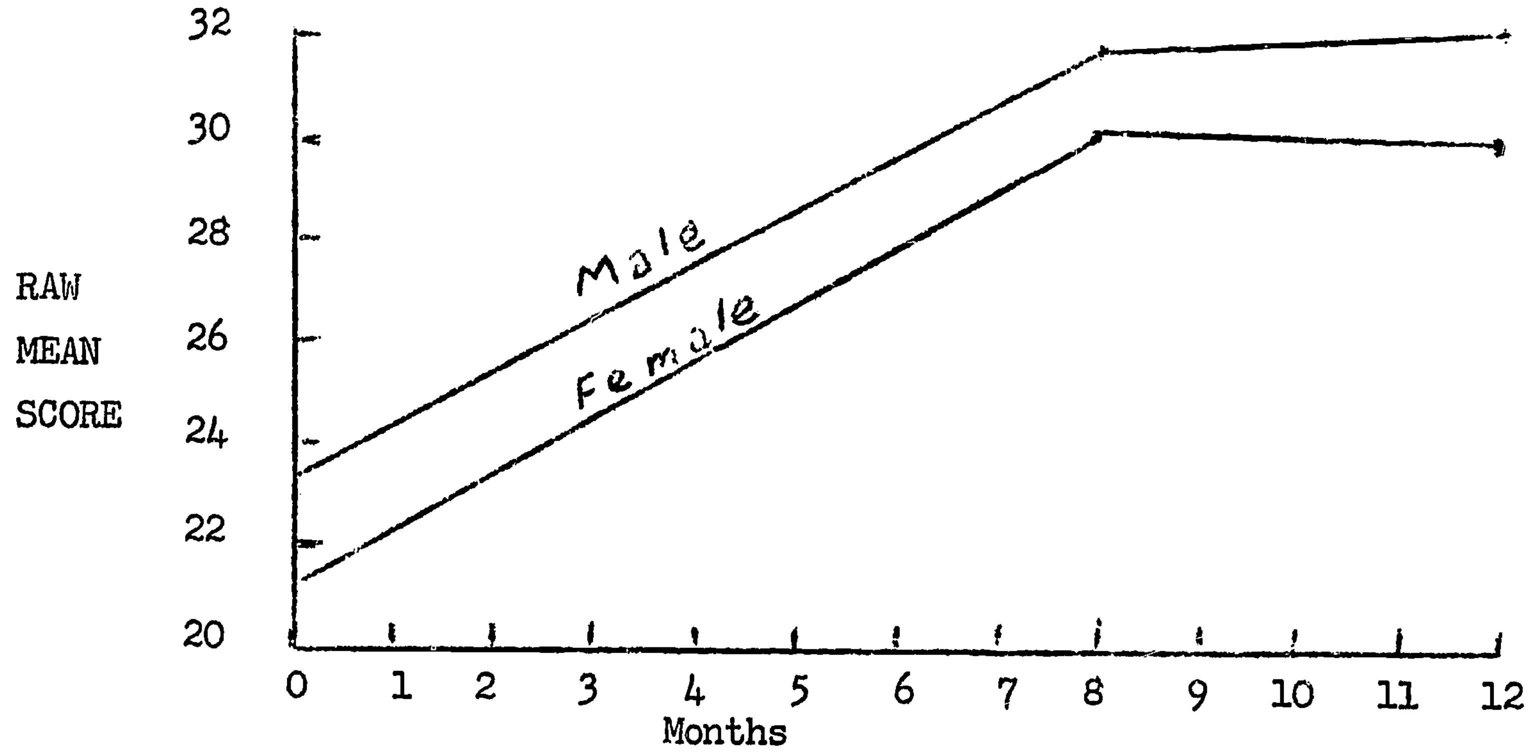


Figure III. - Nelson Biology Test: Male vs. Female

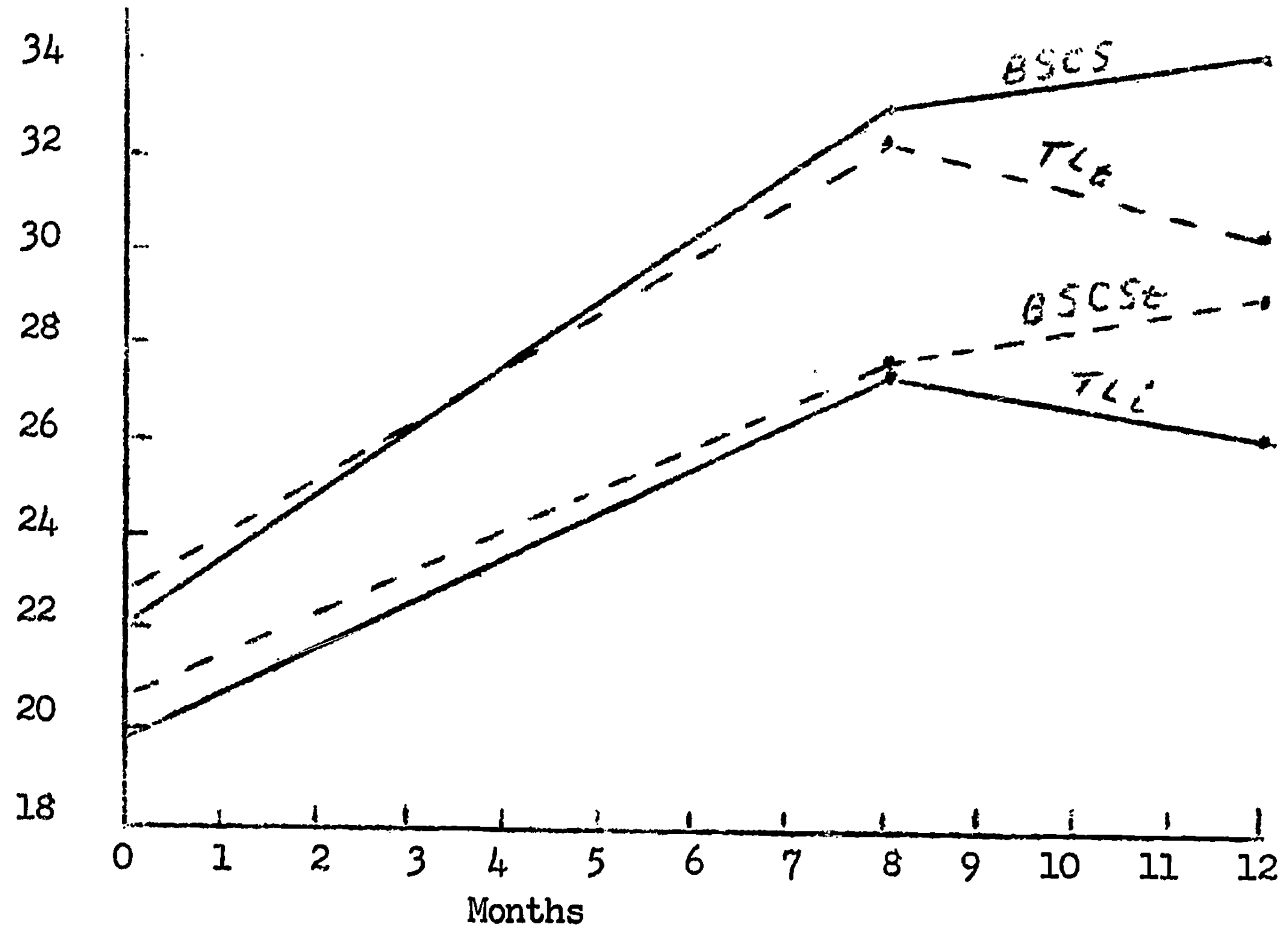


Figure IV. - Nelson Biology Test: $BSCS_i$ vs $BSCS_t$ vs. $TL_i$ vs. $TL_t$

Figure II shows that the tenth grade students made a more rapid gain from pre-test to post-test on the Nelson Biology test than did the ninth grade students. That gain was significant at the 0.05 level as reported in Table 8. Figure II also shows that the tenth grade students continued to gain at a less rapid rate over the summer while the mean score of the ninth grade students remained unchanged from the post-test.

Figure III indicates that the males and females made almost parallel gains from the Nelson Biology pre-test to post-test. From post-test to retention test, Figure III shows that the male students had slight gains and the female students had slight losses.

From the pre-test to post-test on the Nelson Biology test, the $BSCS_i$ subgroup made the most rapid gain in comparison with the other subgroups. See Tables 7 and 8 and Figure IV. The subgroup which made the next most rapid gain from the pre-test to post-test was the $TL_t$ subgroup. The subgroup with the least rapid gain during the period from pre-test to post-test was $BSCS_t$. See Tables 7 and 8, and Figure IV. During the period from post-test to retention test, the $BSCS_i$ and $BSCS_t$ subgroups continued to gain in achievement on the Nelson Biology test while the $TL_i$ and $TL_t$ subgroups lost in achievement.

Tables 11, 12, 13, and 14 correspond to Tables 7, 8, 9, and 10 respectively except that it is the scores on the Processes of Science test which are being compared. Figures V, VI, VII and VIII are the graphs of raw scores on the Processes of Science test which correspond to Figures I, II, III, and IV.

Table 11 reports the data gathered from the Processes of Science post-test. There were no significant differences on the Processes of Science post-test between BSCS and TL, between the ninth grade students and tenth grade students, and between male students and female students as reported in Table 12. In Table 12 it can be seen that the $BSCS_i$ subgroup made significantly higher gains on the Processes of Science test during the pre-test to post-test period than any other subgroup. That difference remained after class size was used as an additional covariate. In one case, $BSCS_i$ versus $TL_t$, when class size was added as a covariate the level of confidence rose from 0.95 to 0.99. See Table 12. There were no significant differences among the comparisons of the other subgroups on the Processes of Science post-test.

Table 13 reports the data from the Processes of Science retention test. Table 14 shows that the BSCS group achieved significantly higher on the Processes of Science retention test than did the TL group. That difference remained after class size was used as an additional covariate. No significant differences were detected between ninth grade students and tenth grade students on this test. Neither were there any significant differences between male and female students. The $BSCS_t$ and the $TL_i$ subgroups both achieved significantly higher scores on the Processes of Science retention test than did the $TL_t$ subgroup. See Table 14. For the $TL_i$ subgroup the level of confidence increased to 0.99 after class size was used as an additional covariate. See Table 14.

Figure V illustrates that there was practically no difference in the BSCS and TL raw scores on the Processes of Science pre-tests and the post-test. On the retention test, however, the BSCS continued to gain while the TL group lost. That difference was significant as was shown in Table 14.

TABLE 11

PROCESSES OF SCIENCE TEST DATA FROM POST-TEST

| Group | Sex | No. | Covar.[a] Mean | Covar.[b] Mean | Std. Dev. | Mean[c] | Mean[d] Change | Total[e] Change |
|---|---|---|---|---|---|---|---|---|
| BSCS | M | 51 | 20.18 | 26.92 | 7.32 | 22.45 | 2.27 | 115.77 |
| BSCS | F | 67 | 19.75 | 26.19 | 6.42 | 21.15 | 1.40 | 93.80 |
| $BS_{10th}$ | M | 25 | 23.56 | 26.88 | 5.40 | 25.28 | 1.72 | 43.00 |
| $BS_{10th}$ | F | 15 | 25.00 | 25.80 | 6.82 | 26.53 | 1.53 | 22.95 |
| TL | M | 44 | 20.00 | 25.30 | 8.02 | 20.70 | 0.70 | 30.80 |
| TL | F | 56 | 21.54 | 27.32 | 7.77 | 23.14 | 1.60 | 89.60 |
| $TL_{10th}$ | M | 28 | 21.64 | 23.88 | 7.25 | 24.14 | 2.50 | 70.00 |
| $TL_{10th}$ | F | 17 | 21.53 | 25.94 | 5.19 | 24.82 | 3.29 | 55.93 |
| $BSCS_i$ | M | 15 | 22.93 | 24.47 | 6.58 | 25.33 | 2.40 | 36.00 |
| $BSCS_i$ | F | 20 | 22.25 | 25.00 | 5.20 | 25.70 | 3.45 | 69.00 |
| $BSCS_t$ | M | 16 | 18.94 | 32.81 | 6.92 | 20.13 | 1.19 | 19.04 |
| $BSCS_t$ | F | 17 | 21.00 | 30.59 | 4.12 | 21.06 | 0.06 | 1.02 |
| $TL_i$ | M | 10 | 15.40 | 22.20 | 8.10 | 17.50 | 2.10 | 21.00 |
| $TL_i$ | F | 18 | 19.11 | 26.17 | 7.72 | 19.44 | 0.33 | 5.94 |
| $TL_t$ | M | 12 | 20.17 | 31.50 | 5.70 | 20.58 | 0.41 | 4.92 |
| $TL_t$ | F | 22 | 22.77 | 30.27 | 7.69 | 23.27 | 0.50 | 11.00 |

[a]The covariate was the Processes of Science pre-test.

[b]The covariate was class size.

[c]Mean of the Processes of Science post-test.

[d]The difference between the first covariate and the Processes of Science post-test.

[e]Mean change times the number of students.

TABLE 12

RESULTS OF ANALYSIS OF COVARIANCE: PROCESSES OF SCIENCE POST-TEST

| Comparisons | Mean Difference[a] | D.F. | F-Test | Difference in Class Size[b] | F-Test[c] |
|---|---|---|---|---|---|
| BSCS | 0.04 | 1, 294 | 0.07 | 0.62 | 0.07 |
| 9th vs 10th | -0.75 | 1, 294 | 3.38 | 0.96 | 3.34 |
| Male vs Female | 0.06 | 1, 294 | 0.17 | -0.68 | 0.17 |
| $BSCS_i$ vs $BSCS_t$ | 2.39 | 1, 63 | 6.91* | -6.90 | 6.65* |
| $BSCS_i$ vs $TL_i$ | 2.04 | 1, 58 | 4.06* | 0.02 | 4.28* |
| $BSCS_i$ vs $TL_t$ | 2.56 | 1, 64 | 5.11* | -5.93 | 9.92** |
| $BSCS_t$ vs $TL_i$ | -0.35 | 1, 56 | 0.01 | 6.92 | 0.23 |
| $BSCS_t$ vs $TL_t$ | 0.17 | 1, 62 | 0.01 | 0.97 | 0.03 |
| $TL_i$ vs $TL_t$ | 0.49 | 1, 57 | 0.46 | -5.95 | 1.35 |

[a]Mean change of the first group minus mean change of second group.

[b]Average class size of the first group minus average class size of the second group.

[c]In addition to the pre-test, class size was used as a covariate.

*Significant at the 0.05 level.

**Significant at the 0.01 level.

TABLE 13

PROCESSES OF SCIENCE TEST DATA FROM RETENTION TEST

| Group | Sex | No. | Covar. Mean[a] | Covar. Mean[b] | Dev. | Mean[c] | Mean Change[d] | Total Change[e] |
|---|---|---|---|---|---|---|---|---|
| BSCS | M | 51 | 22.45 | 26.92 | 7.22 | 22.92 | 0.47 | 23.97 |
| BSCS | F | 67 | 21.15 | 26.19 | 7.26 | 21.21 | 0.06 | 4.02 |
| $BS_{10th}$ | M | 25 | 25.28 | 26.88 | 6.63 | 25.48 | 0.20 | 5.00 |
| $BS_{10th}$ | F | 15 | 26.53 | 25.80 | 7.56 | 28.07 | 1.54 | 23.10 |
| TL | M | 44 | 20.70 | 25.30 | 8.67 | 20.14 | -0.56 | -24.64 |
| TL | F | 56 | 23.14 | 27.32 | 7.27 | 23.86 | 0.72 | 40.32 |
| $TL_{10th}$ | M | 28 | 24.14 | 23.88 | 8.45 | 22.00 | -2.14 | -59.92 |
| $TL_{10th}$ | F | 17 | 24.82 | 25.94 | 5.36 | 23.88 | -0.94 | -15.98 |
| $BSCS_i$ | M | 15 | 25.33 | 24.47 | 7.50 | 25.07 | -0.26 | -3.90 |
| $BSCS_i$ | F | 20 | 25.70 | 25.00 | 7.16 | 24.45 | -1.25 | -25.00 |
| $BSCS_t$ | M | 16 | 20.13 | 32.81 | 5.74 | 22.56 | 2.43 | 38.88 |
| $BSCS_t$ | F | 17 | 21.06 | 30.59 | 4.01 | 23.12 | 2.06 | 35.02 |
| $TL_i$ | M | 10 | 17.50 | 22.20 | 8.34 | 18.70 | 1.20 | 12.00 |
| $TL_i$ | F | 18 | 19.44 | 26.17 | 7.98 | 21.11 | 1.67 | 30.06 |
| $TL_t$ | M | 12 | 20.58 | 31.50 | 7.43 | 18.17 | -2.41 | -28.92 |
| $TL_t$ | F | 22 | 23.27 | 30.27 | 6.81 | 23.14 | -0.13 | -2.86 |

[a]The covariate was the Processes of Science post-test.

[b]The covariate was the class size.

[c]Mean of the Processes of Science retention test.

[d]The difference between the first covariate and the Processes of Science retention test.

[e]Mean change times the number of students.

TABLE 14

RESULTS OF ANALYSIS OF COVARIANCE: PROCESSES OF SCIENCE RETENTION TEST

| Comparisons | Mean Difference[a] | D.F. | F-Test | Difference in Class Size[b] | F-Test[c] |
|---|---|---|---|---|---|
| BSCS | 0.78 | 1, 294 | 4.88* | 0.62 | 4.46* |
| 9th vs 10th | 0.76 | 1, 294 | 0.07 | 0.96 | 0.15 |
| Male vs Female | -0.71 | 1, 294 | 2.42 | -0.68 | 2.23 |
| $BSCS_i$ vs $BSCS_t$ | -3.07 | 1, 63 | 0.86 | -6.90 | 1.49 |
| $BSCS_i$ vs $TL_i$ | -2.33 | 1, 58 | 2.65 | 0.02 | 2.47 |
| $BSCS_i$ vs $TL_t$ | 0.10 | 1, 64 | 0.68 | -5.93 | 2.89 |
| $BSCS_t$ vs $TL_i$ | 0.74 | 1, 56 | 1.40 | 6.92 | 0.69 |
| $BSCS_t$ vs $TL_t$ | 3.17 | 1, 62 | 6.55* | 0.97 | 6.22* |
| $TL_i$ vs $TL_t$ | 2.43 | 1, 57 | 5.55* | -5.95 | 11.16** |

[a]Mean change of the first group minus mean change of the second group.

[b]Average class size of the first group minus average class size of the second group.

[c]In addition to the Processes of Science post-test class size was used as a covariate.

*Significant at the 0.05 level.

**Significant at the 0.01 level.

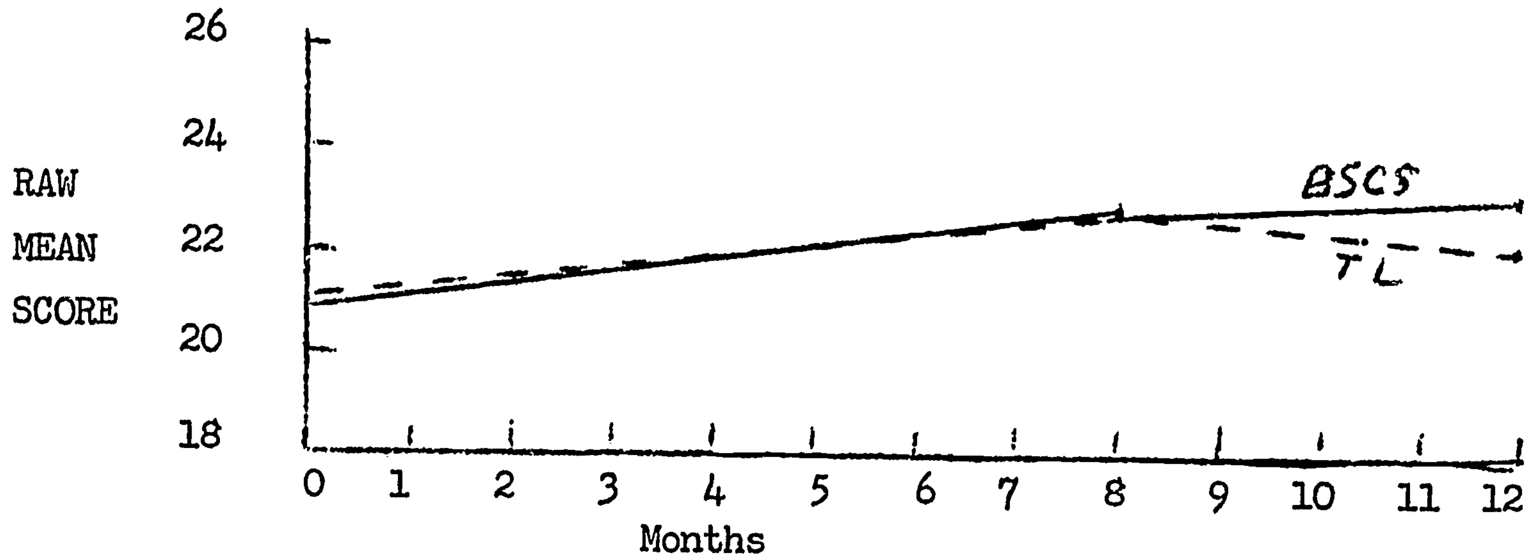


Figure V. - Processes of Science Test: BSCS vs. TL

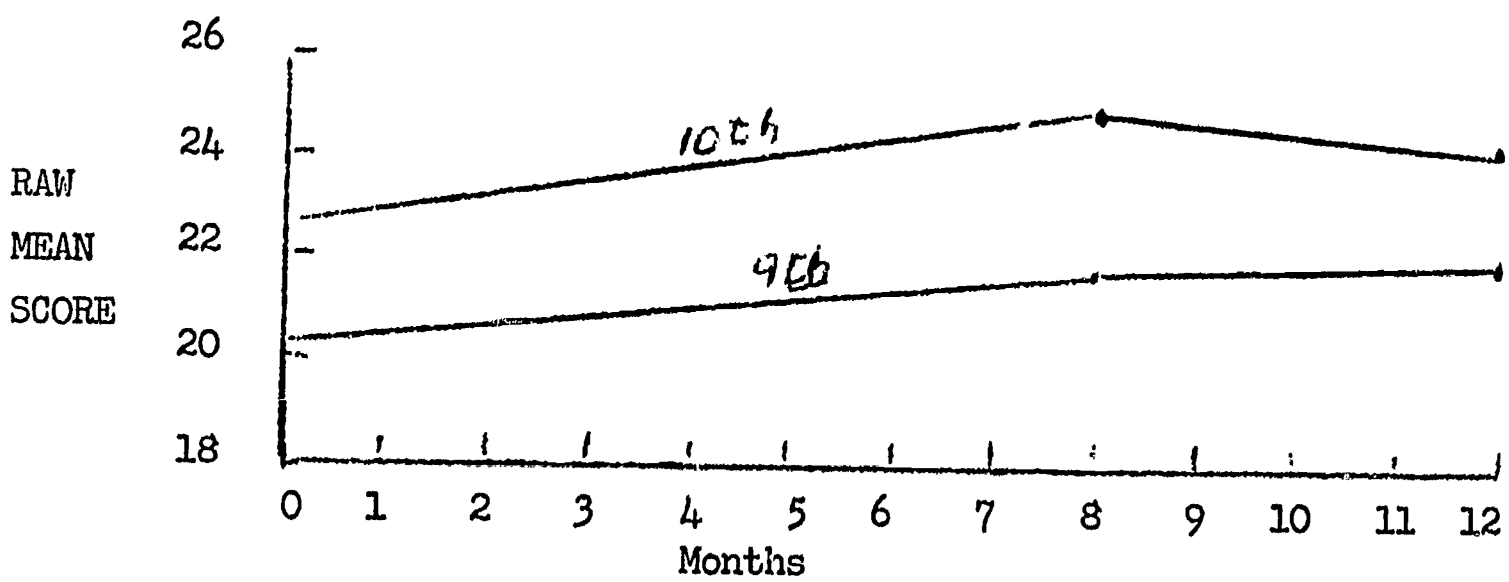


Figure VI. - Processes of Science Test: 9th vs. 10th.

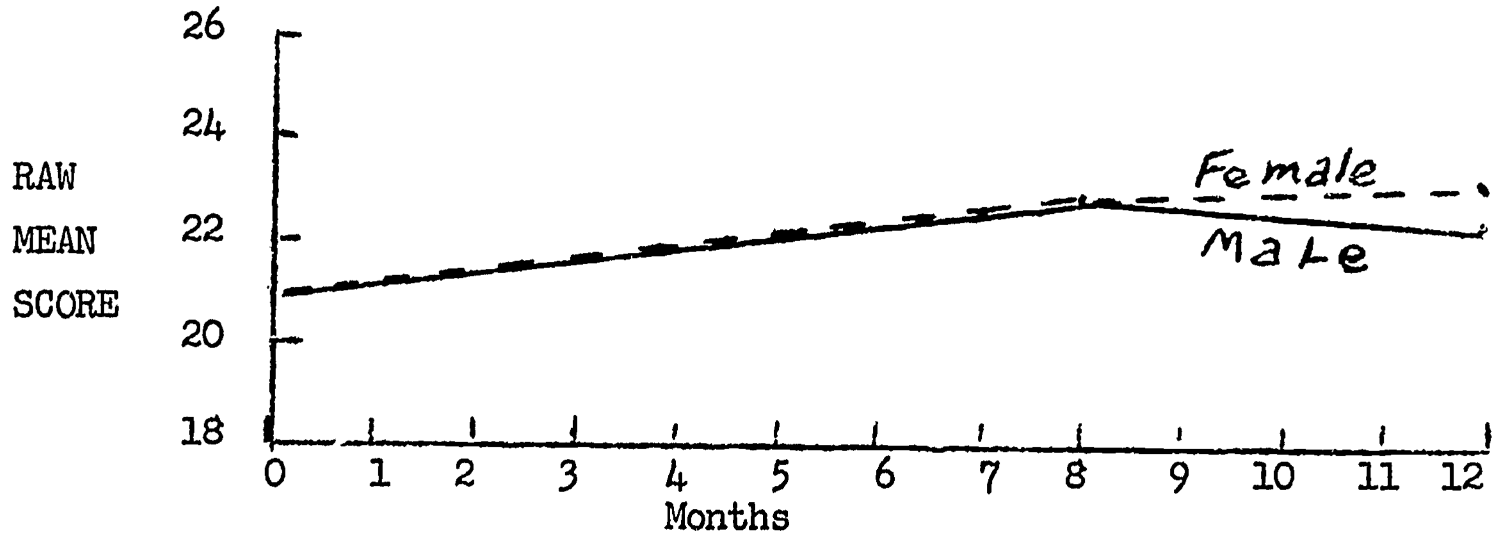


Figure VII. - Processes of Science Test: Male vs. Female

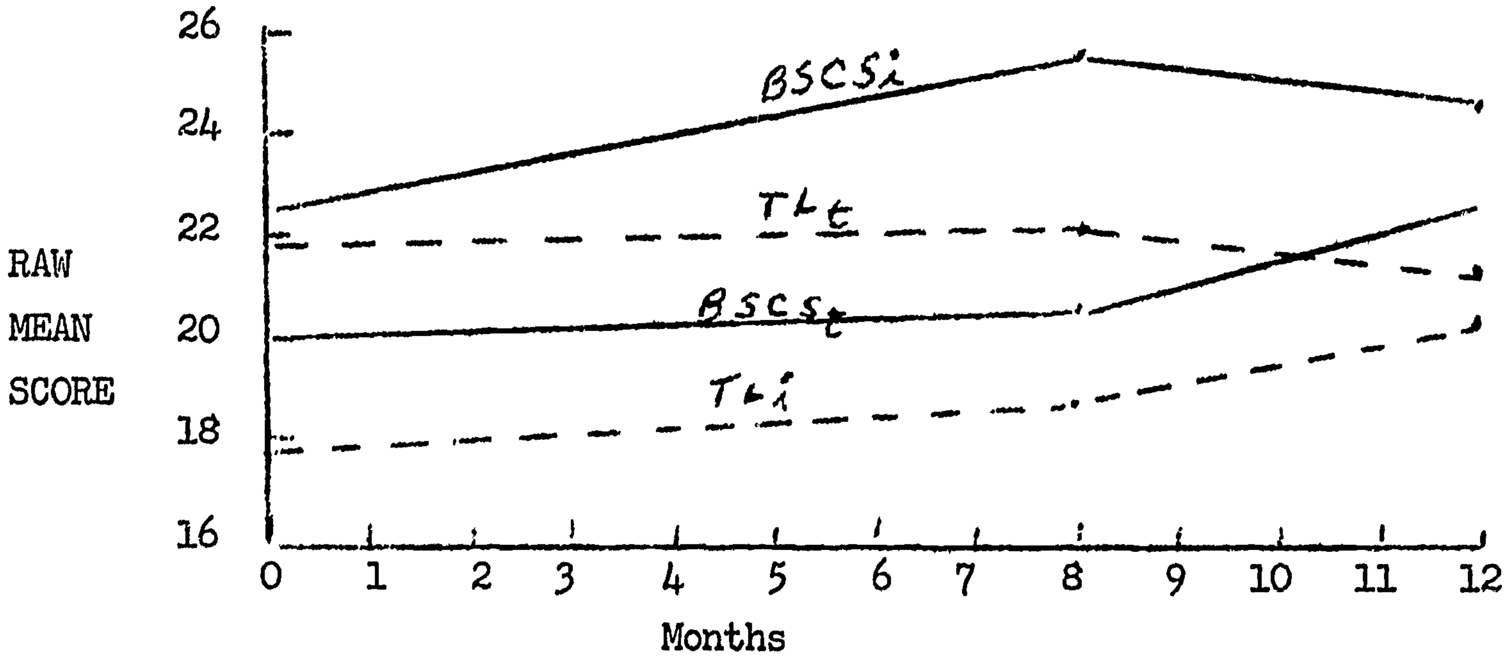


Figure VIII. - Processes of Science Test: $BSCS_i$ vs. $BSCS_t$ vs. $TL_i$ vs. $TL_t$

In Figure VI it can be seen that the ninth grade and tenth grade students made practically parallel gains from the pre-test to the post-test on the Processes of Science test. From the post-test to the retention test, the ninth grade students had a slight gain in achievement while the mean of the tenth grade students was reduced during that period on the Processes of Science test. The difference was not statistically significant.

Figure VII shows that the male and female students had parallel gains on the Processes of Science test during the period from the pre-test to the post-test. The females made a slight gain from post-test to retention test while the males had a loss of achievement during this period. The difference was not statistically significant.

Figure VIII compares the raw scores of the subgroups on the Processes of Science test. The $BSCS_i$ subgroup made the most rapid advance of all the subgroups during the pre-test to post-test period. As shown in Table 12, that difference was significant. During the post-test to retention test period, the $BSCS_i$ and the $TL_t$ subgroups had a decrease in their mean while the $BSCS_t$ and the $TL_i$ had a gain in their mean for the same period. As shown in Table 14, that gain was statistically significant when compared with the $TL_t$ subgroup, but was not statistically significant over the $BSCS_i$ subgroup.

B. Interpretation of Data

Many science educators who are writing about modern science education, Hurd (65), Marshall and Burkman (84), Lee (79), Grobman (51), and Tyler (119), have made the point that knowledge should be durable and that students should be capable of continuing to learn after high school. Grobman (51) and Glass (46) have said that one of the aims of the BSCS biology was to develop informed citizens which implies greater retention of biological knowledge and a continuation of learning. An examination of the data supports the view that BSCS biology aids student retention of biological knowledge. The data reveals the following facts in support of the view that BSCS biology aids retention of biological knowledge: (a) The BSCS group significantly exceeded the TL group on both the Nelson Biology Test and the Processes of Science Test on retention tests; see Tables 10 and 14 and Figures I and V. (b) The $BSCS_i$ subgroup gained significantly more than the $TL_i$ subgroups on both retention tests; see Tables 10 and 14 and Figures IV and VIII. (c) The $BSCS_i$ subgroup gained significantly more than the $TL_t$ subgroup on the Processes of Science retention test; see Table 14 and Figure VIII. (d) The $BSCS_t$ subgroup had a significant gain over the $TL_t$ subgroup on the Processes of Science retention test; see Table 14 and Figure VIII. (e) Figures I and IV show that the BSCS group and the $BSCS_i$ and $BSCS_t$ subgroups made positive gains from the post-test to the retention test on the Nelson Biology test. (f) The BSCS group and the $BSCS_t$ subgroup also made positive gains from the post-test to retention test on the Processes of Science test; see Figures V and VIII. (g) The TL group and $TL_i$ and $TL_t$ subgroups had losses on the Nelson Biology test during the period from post-test to retention test; see Figures I and IV. (h) The TL group and the $TL_t$ subgroup also had losses on the Processes of Science retention test; see Figures V and VIII.

Many BSCS writers, including Hurd (65), Tyler (119), Arnold Grobman (51), Glass (46), Lee (78), and Hulda Grobman (53), have advocated the use of inquiry as a teaching method. They have contended that the use of inquiry would increase retention of biology concepts and enable the student to continue learning after leaving biology. The data from this research lends support to the view that inquiry at least increases retention. The following points are clear from the data: (a) The mean gain of the $BSCS_i$ subgroup exceeded the mean gain of the other subgroups by a statistically significant amount on the Processes of Science post-test; see Table 12 and Figure VIII. (b) The mean gain of the $TL_i$ subgroup exceeded the mean gain of the $TL_t$ subgroup by a statistically significant amount on the Processes of Science retention test; see Table 12 and Figure VIII. (c) The inquiry subgroups were not significantly exceeded in mean gain on the Nelson Biology or the Processes of Science tests on either the post-tests or retention tests by the traditional subgroups; see Tables 12 and 14. (d) The inquiry rating of the BSCS group was higher than the inquiry rating for the TL group on all factors rated. A portion of the advantage that the BSCS groups had over the TL groups may have been due to teaching method. It is particularly noteworthy that the BSCS mean test rating was 12 points higher than the TL mean test rating, as shown in Table 5.

The trends of the scores on the two tests which were used, the Nelson Biology test and the Processes of Science test, followed each other closely. Two possibilities suggest themselves: (a) both tests measure the same factor, or (b) the factors measured by the tests are closely associated. A third possibility might be a combination of the first two. A difference which existed between the two tests is that the Nelson Biology test showed a greater raw score change from one testing to the next than did the Processes of Science test.

Among the subgroups the coupling of the inquiry teaching methods with the BSCS materials apparently produced the most effective way of learning inquiry concepts as measured by the Processes of Science test. That result is apparent in Table 12 and Figure VIII. The $BSCS_i$ subgroup also, significantly, outperformed the $BSCS_t$ and $TL_i$ subgroups on the Nelson Biology post-test and the $BSCS_i$ maintained the advantage on the Nelson Biology retention test.

Except for the $BSCS_i$ subgroup, the $TL_i$ subgroup was not significantly outperformed by any other subgroups. See Tables 8, 10, 12 and 14. The $TL_i$ subgroup did make a statistically higher mean gain on the Processes of Science retention test than did the $TL_t$ subgroup. See Table 14 and Figure VIII. On the same test the $BSCS_t$ subgroup also had a statistically higher mean gain than did the $TL_t$ subgroup. See Table 14 and Figure VIII. No significant differences were found between the $TL_i$ and $BSCS_t$ subgroups.

Class size did not have much influence on the significance of the results. In Table 8 it can be seen that the BSCS group had a significantly higher mean gain on the Nelson Biology post-test than the TL group until class size was considered. Where class size was used as an additional covariate the significance was negated. The average class size of the BSCS group was 0.62 higher than the average class size of the TL group. It might be expected that the larger class size of the BSCS groups could merit a positive adjustment in their F-test scores. Such was not the case however; since there was a positive correlation between class size and test scores-the larger classes tended to score higher on the tests-the F-test was adjusted in favor of the TL group, the group with the smaller classes.

In Table 12 and Table 14 class size had a similar effect on the F-test. In Table 12 the $BSCS_i$ subgroup averaged 5.93 students less per class than the $TL_t$ subgroup. Again there was a positive correlation between the class size and the Processes of Science post-test mean, thus the F-test was adjusted in favor of the $BSCS_i$ subgroup, the group with the smaller classes. The adjusted F-test raised the level of significance from 0.05 to 0.01. In Table 14 the same phenomena is repeated in the comparison of the $TL_i$ and $TL_t$ subgroups. In this case it is the $TL_i$ subgroup which had the smaller classes and received the benefit of the adjusted F-test.

It is difficult to know how to interpret the effect of class size. The larger classes tended to score higher on the tests than the smaller classes. It does not seem reasonable that class size alone would cause the higher scores of the larger classes. The correlation between class size and test scores was low, 0.25, but significant at the 0.05 level. The differences in most cases between average class sizes were also low. See Tables 7 and 8. The $BSCS_i$ and the $TL_i$ subgroups were composed of smaller classes than the $BSCS_t$ and the $TL_t$ subgroups. It may be that it was easier to follow the inquiry teaching method with smaller classes. The relationship between class size and test score, however, is not readily apparent to this investigator. Until further analysis can be conducted to clear up the relationship between class size and test score, the differences revealed by the first F-test will be emphasized.

Contrary to the reports of Yager (128, 129) a significant difference was found in this research between ninth and tenth graders. The tenth grade students scored significantly higher on the Nelson Biology post-test than did the ninth grade students. See Table 8 and Figure II. The tenth grade students maintained their advantage on the Nelson Biology retention test. No other significant differences were found between ninth and tenth grade students. See Table 8 and Figure II.

The sex of the student was not found to cause any significant differences in the learning of the students. The raw scores for the males on the Nelson Biology test were higher than the scores for the females, which would agree with the findings of Hulda Grobman (57). However, the change in scores were not significantly different for the sexes. On the Processes of Science Test the females outscored the males by a fraction of a point, but the difference is so small that it is probably inconsequential.

To say why the BSCS groups generally outperformed the TL groups and the inquiry subgroups performed better than the traditional subgroups on these tests would be going beyond the data of this research. The BSCS writers and experimental psychologists have suggested a number of factors which can influence learning and retention. Among the factors which have been suggested are: (a) making the subject meaningful to the student; (b) increase the motivation of the student by raising interest, and (c) allow the students to discover answers to problems themselves rather than teachers supplying answers. A wide variety of other possibilities also exist such as teacher enthusiasm, and, as Bruner (21) suggests, increased emphasis on the structure of biology. The BSCS writers claim that their materials, Schwab (104), place less emphasis on facts, deal with more modern biology concepts, and increase the emphasis on broad concepts and principles than do the traditional materials.

Any of the preceding factors may have influenced the results. However, it was the objective of this study to find out what was happening in the field. An explanation of why it may have happened in this way has been discussed by other writers in other places. This researcher believes that the objective of the study has been met.

# V. SUMMARY AND CONCLUSIONS

## A. Summary of Research Problem and Method

The purpose of this study was to examine the effects of the BSCS materials and the inquiry teaching method on student achievement and retention in biology. Schwab (104), Lee (78), and others have indicated that the philosophy of BSCS biology is that it was to be taught by the method of inquiry. The wide adoption of the BSCS materials have made it desirable to determine how effectively the teachers of BSCS biology are meeting that philosophy, and to determine if achievement and retention are effected by the materials and the teaching method. Teachers using the BSCS materials could teach biology by either the method of inquiry or the traditional method. Thus the affects of the teaching method on achievement and retention of biology could be measured by standardized tests. The inquiry approach could also be used in the teaching of traditional biology. Again, the inquiry and traditional teaching methods could be compared in their effects on achievement and retention in biology classes using the traditional type text.

A review of the literature revealed that most evaluation of student achievement with the BSCS materials had been done by researchers closely associated with BSCS. Lisonbee and Fullerton (82) have conducted an independent study of BSCS biology achievement that was limited to Phoenix, Arizona. The effects on achievement and retention of using an inquiry

approach with the teaching of BSCS biology has not been explored by other researchers so far as is known to this investigator. Descriptions of the BSCS materials and the philosophy of teaching by inquiry can be found in the writings of the following: Glass (46), Goodlad (48), Grobman (52), Heath (62), Metzner (88), and Schwab (104).

From East Central and Northeastern Indiana schools 28 teachers were selected along with a random selection of 12 students from each teacher to participate in the study. The students were given pre-tests, post-tests, and retention tests on both the Nelson Biology test and the Processes of Science test. In order to determine which teachers were using inquiry, each teacher was observed and rated on an inquiry rating scale developed by the researcher. To determine further the amount of emphasis placed on inquiry, teacher-made tests were collected from the teachers, and the percent of inquiry was used as another rating guide. The three ratings, two observations and the test rating, were averaged to give a composite score. The three teachers with the highest composite scores and the three teachers with the lowest scores from each group, BSCS and TL, were then respectively designated as inquiry and traditional in teaching approach. Background information on each school, teacher, and student was gathered and has been presented. See Tables 1 through 6.

In order to reduce the effect of teacher personality as a factor affecting achievement, only a few students of a particular teacher were included in a subgroup, and each subgroup was composed of three teachers. It may be, however, that teacher personality determined the type of teaching method chosen.

The groups selected for comparison were made up of (a) 158 students using BSCS materials, (b) 145 students using traditional materials, (c) 148 male students versus 155 female students, and (d) 218 ninth grade students versus 85 tenth grade students. The subgroups selected were (a) 35 students under the inquiry teaching method and using BSCS materials, (b) 33 students using BSCS materials under a traditional teaching method, (c) 28 students under the inquiry teaching method and using traditional materials, and (d) 34 students using traditional materials and under a traditional teaching method.

Analysis of covariance was used to compare the groups and subgroups. The pre-test was first used as the covariate followed by class size as a concomitant covariate where the post-test was the basis of comparison. To compare the results of the retention test, the post-test was used as the covariate and then class size was again used as an additional covariate.

B. <u>Summary of Results and Conclusions</u>

The teachers using BSCS materials generally rated higher on the inquiry rating scale than did the teachers using traditional materials. The inquiry rating, 27.9, given the tests of the BSCS teachers was also higher than the rating, 15.9, given the tests of the TL teachers.

To facilitate statistical comparisons, 36 null hypotheses were formulated. See pages 5 and 6. The following null hypotheses were accepted: 1.1, 1.2, 2.2, 2.3, 2.4, 3.1, 3.2, 3.3, 3.4, 4.3, 4.4, 5.3, 5.4, 6.1, 6.3, 6.4, 7.1, 7.2, 7.3, 7.4, 8.1, 8.2, 8.3, 9.1, 9.2, and 9.3. The following null hypotheses were rejected: 1.3, 1.4, 2.1, 4.1, 4.2, 5.1, 5.2, 6.2, 8.4, and 9.4. It will be noted that no significant differences were found between males and females or between the $BSCS_t$ subgroup and the $TL_i$ subgroup.

Restating the rejected hypotheses to make them acceptable, they become:

1. The BSCS group achieved significantly higher than the

   1.3-TL group on the Nelson Biology retention test.
   1.4-TL group on the Processes of Science retention test.

2. The ninth grade students achieved significantly less than the

   2.1-tenth grade students on the Nelson Biology post-test.

4. The $BSCS_i$ subgroup achieved significantly higher than the

   4.1-$BSCS_t$ subgroup on the Nelson Biology post-test.
   4.2-$BSCS_t$ subgroup on the Processes of Science post-test.

5. The $BSCS_i$ subgroup achieved significantly higher than the

   5.1-$TL_i$ subgroup on the Nelson Biology post-test.
   5.2-$TL_i$ subgroup on the Processes of Science post-test.

6. The $BSCS_i$ subgroup achieved significantly higher than the

   6.2-$TL_t$ subgroup on the Processes of Science post-test.

8. The $BSCS_t$ subgroup achieved significantly higher than the

   8.4-$TL_t$ subgroup on the Processes of Science retention test.

9. The $TL_i$ subgroup achieved significantly higher than the

   9.4-$TL_t$ subgroup on the Processes of Science retention test.

From the results obtained, the following conclusions seem plausible:

(a) The BSCS materials generally improve the retention of biological knowledge.

(b) Tenth grade biology students learn biology facts and concepts more rapidly than ninth grade students.

(c) The inquiry teaching method coupled with the BSCS materials apparently results in the greatest post-test achievement.

(d) The use of inquiry with traditional materials is at least as effective as the traditional approach with those materials.

(e) There are no significant differences between males and females on biology achievement and retention tests.

C. Limitations of the Research

This research was limited in a number of ways. A major weakness in the design is that the uniformity of the testing situations could not be assured. Each school system was responsible for administering the tests to its students. Another problem was that each school system was responsible for submitting the class lists of biology students; if a student was selectively omitted from that list, he had no chance of being included in the research.

The research was limited by the number of schools and students that could be included in the research. The number of schools and teachers involved limited the number of times this researcher could observe and rate each teacher in his uso of inquiry. More observations by an independent observer would have increased the confidence that could be placed on the Inquiry Rating Scale.

The research was designed to report what happened to student biology achievement and retention, and not why it happened. Of course, we could say that BSCS materials or the inquiry teaching method had the effect of increasing significantly the scores on certain tests at certain times, but to say why BSCS materials increased student retention of biological information or why the inquiry teaching method caused students to continue learning during the summer is beyond the scope of this data.

D. Recommendations

In view of the findings in Chapter IV, this investigator recommends that school administrators and teachers give serious consideration to adopting BSCS biology materials. The version which is adopted would depend upon the school situation and environment. It is further recommended that teachers at least give the inquiry method a fair trial in their classes. The teachers should first become familiar with the inquiry technique. Second, they might give inquiry a limited trial with a portion of the biology course to one biology class. The teachers could then compare the behavioral outcomes of that class with those of another class of similar ability. As a control, another portion of the biology course could be taught to a second biology class by the inquiry method and to the first class by the standard procedure for that teacher, and the behavioral outcomes could again be compared.

Many teachers and administrators are under the impression that to teach BSCS biology requires sophisticated equipment and extensive laboratory facilities. While this impression cannot be catagorically denied, the equipment and facilities for BSCS biology need not be nearly as sophisticated or as extensive as many teachers and administrators seem to believe. It is true that more equipment and better facilities are needed for BSCS biology than for the standard procedures of dissections and collections which constitute the laboratory activities of some traditional biology courses. To teach any modern biology laboratory course, however, requires more equipment and better facilities than have been allotted to biology in the past.

Further research is needed to determine what factors of BSCS biology cause the increased retention. The optimum level of use of the inquiry teaching approach needs further exploration. The figures that were presented in Chapter IV were based on the assumption that learning occurred in direct proportion to the amount of time spent in the biology course. Reasoning dictates that the assumption is not true. A learning curve would be a very valuable addition to our knowledge of the learning of science material. Once a learning curve were established, factors influencing a change in the curve could be explored which would have tremendous implications for students, teachers, and administrators.

## VI. BIBLIOGRAPHY


1. Abraham, Norman. 1964. "Letter to the Editor," The American Biology Teacher. 26:263-264.

2. Alexander, William M. 1967. The Changing Secondary School Curriculum. New York: Holt, Rinehart and Winston. 479 pp.

3. Amaro, A. 1964. "Considerations Upon the BSCS, (Green Version)" The American Biology Teacher. 26:347.

4. Anonymous. 1963. "About BSCS Biology," BSCS Newsletter. 17:7-15.

5. Atkin, J. Myron. 1956. "Analysis of the Development of Elementary School Children in Certain Selected Aspects of Problem-Solving Ability," Unpublished doctoral dissertation, New York University.

6. Ausubel, David P. 1966. "An Evaluation of the BSCS Approach to High School Biology," The American Biology Teacher. 28:176-186.

7. ————. 1965. "An Evaluation of the Conceptual Schemes Approach to Science Curriculum Development," Journal of Research in Science Teaching. 3:255-264.

8. ————. 1963. "Some Psychological and Educational Limitations of Learning by Discovery," The New York State Mathematics Teachers Journal. 8:90-108.

9. Aylesworth, Thomas G. 1962. "Four Kinds of Thinking in the Biology Classroom," The American Biology Teacher. 24:597-599.

10. Barnes, Lehman W. 1967. "The Nature and Extent of Laboratory Instruction in Selected Modern High School Biology Classes," (abstract of unpublished Ph.D. dissertation, The University of Texas, 1966) BSCS Newsletter. 30:23.

11. Barry, David G. 1965. "Early American Science and the Roots of Modern Biology," The American Biology Teacher. 27(8):600-606.

12. Behringer, Marjorie P. 1967. "The Development of Differentiated Curricula for Ability Grouped Biology Classes, Including Teacher Training and Program Evaluation," BSCS Newsletter. 30:23.

13. Belanger, Maurice. 1964. "The Study of Teaching and the New Science Curricula," The Science Teacher. 31(7):31-35.

14. Blankenship, Jacob W. 1966. "The Effectiveness of Four Methods of Determining Science Teacher Attitudes Toward a New Biology Program," School Science and Mathematics. 66:831-837.

15. Blankenship, Jacob W. 1965. "Biology Teachers and Their Attitudes Concerning BSCS," Journal of Research in Science Teaching. 3:54-60.

16. Bloom, Benjamin S. 1966. Taxonomy of Educational Objectives: Cognitive Domain. New York: David McKay Co., Inc. pp. 1-207.

17. Brandwein, Paul F. 1963. "On Beginning," Research Problems in Biology: Investigations for Students." Series One, Biological Sciences Curriculum Study, Garden City, New York: Anchor Books, Doubleday and Company, Inc. 237 pp.

18. Bruner, Jerome S. 1966. Toward a Theory of Instruction. Cambridge: The Belknap Press of Harvard University Press. 176 pp.

19. ————. 1965. "Liberal Education for All Youth," The Science Teacher. 32(8):19-21.

20. ————. 1962. On Knowing: Essays for the Left Hand. Cambridge: The Belknap Press of Harvard University Press. 165 pp.

21. ————. 1960. The Process of Education. Cambridge, Mass.: Harvard University Press. 97 pp.

22. Bruner, Jerome S., Goodnow, Jacqueline J., and Austin, George A. 1956. A Study of Thinking. New York: John Wiley and Sons, Inc. 330 pp.

23. BSCS. 1963. Biological Science: An Inquiry Into Life (Yellow Version). Chicago: Harcourt, Brace and World, Inc. 748 pp.

24. BSCS. 1963. Biological Science: Molecules to Man (Blue Version). Boston: Houghton Mifflin Company. 716 pp. + L 130 pp.

25. BSCS. 1963. High School Biology. Chicago: Rand McNally and Company. 749 pp. (Green Version)

26. Butts, David P. 1963. "Does Experience Equal Understanding?" The Science Teacher. 30(8):81-82.

27. Carin, Arthur and Sund, Robert B. 1964. Teaching Science Through Discovery. Columbus, Ohio: Charles E. Merrill Books, Inc. 514 pp.

28. Cornelius, Marion E. 1965. "BSCS Motivates Students," School and Community. 52:28-29.

29. Craig, Robert C. 1953. The Transfer Value of Guided Learning. New York: Teachers College, Columbia University, Bureau of Publications. 85 pp.

30. Crossland, Richard W. 1964. "The American Biological Sciences Curriculum Study," The American Biology Teacher. 26(5); 348-353.

31. Davis, Jerry B. 1966. "The BSCS Program's Variable Factor," Science Education. 50(3):221-222.

32. Defler, Donald J. 1966. "Using Closed Circuit Television with Biological Science Curriculum Studies Material," The American Biology Teacher. 28:699-703.

33. Dewey, John. 1916. "Method in Science Teaching," General Science Quarterly. 1(1):3

34. Downie, N. M. and Heath, R. W. 1959. Basic Statistical Methods. New York: Harper and Row, Publishers. 289 pp.

35. Dubos, Daedalus Rene. 1965. "Science and Man's Nature," Journal of the American Academy of Arts and Sciences. 94:233-244.

36. Easley, J. A., Jr., Kendziar, Elizabeth, and Wallace, Robert. 1967. "A Bio-Assay of Biology Tests," The American Biology Teacher. 29:382-389.

37. Fischler, Abraham S. 1965. "Science, Process, the Learner: A Synthesis," Science Education. 49(5):402-409.

38. Fish, Alphoretta S., and Goldmark, Bernice. 1966. "Inquiry Method: Three Interpretations," The Science Teacher. 33(2):13-15.

39. Fordyce, Phillip R. 1962. "Rushin' Menace," The American Biology Teacher. 24:564.

40. Fowler, H. Seymour. 1964. Secondary School Science Teaching Practices. New York: The Center for Applied Research in Education, Inc. 113 pp.

41. Fowler, H. Seymour. 1963. "Modern Biology for Whom?" The American Biology Teacher. 24:4.

42. Frankel, Edward. 1962. "BSCS, Where New Horizons Begin," Science Teacher. 29:47-51.

43. Gallagher, James J. 1967. "Teacher Variation in Concept Presentation in BSCS Curriculum Program," BSCS Newsletter. 30:8-18.

44. Geisert, Paul. 1965. "Memory vs. Creative Thinking," The American Biology Teacher. 27:759.

45. George, Kenneth D. 1965. "The Effect of BSCS and Conventional Biology on Critical Thinking," Journal of Research in Science Teaching. 3:293-299.

46. Glass, Bentley. 1962. "Renascent Biology: A Report on the AIBS Biological Sciences Curriculum Study," The School Review. 70:16-43.

47. Goldstein, Philip. 1965. "What Kind of Biology?" The American Biology Teacher. 27:588+

48. Goodlad, John I., Stoephosius, Renata Von, and Klein, M. Frances. 1966. The Changing School Curriculum. New York: The Fund for the Advancement of Education. 9-122.

49. Goodlad, John I. 1964. "Curriculum Reform Sorts Out Basic Concepts," The Nation's Schools. 73:68-70.

50. Gregory, William H. and Goldman, Edward H. 1965. Biological Science for High School. Chicago: Ginn and Company. 820 pp.

51. Grobman, Arnold. 1967. "School Biology of the Future: Some Considerations," The American Biology Teacher. 29:351-355.

52. Grobman, Arnold. 1964. "My Reaction Is . . ." BSCS Newsletter. 22:7-11.

53. Grobman, Hulda. 1967. "Pedagogy to Fit Materials," The American Biology Teacher. 29:340.

54. ————. 1966. "Why Aren't There More Good Teachers?" The American Biology Teacher. 28:164+

55. ————. 1965. "Assignment of Students to Tracks in Biology," The American Biology Teacher. 27:762-764.

56. ————. 1965. "Needed Research in High School Biology," The American Biology Teacher. 27:705-707.

57. ————. 1963. "Some Comments on the Evaluation Program Findings and Their Implications," BSCS Newsletter. 19:25-29.

58. ————. 1963. "The Rationale and Framework of the BSCS Evaluation Program," BSCS Newsletter. 19:6-11.

59. Grobstein, Clifford. 1966. "Defining the Core of a Science," The American Biology Teacher. 28:804-808.

60. Haslerud, George M., and Meyers, Shirley. 1958. "The Transfer Value of Given and Individually Derived Principles," The Journal of Educational Psychology. 49(6):293-298.

61. Hastings, J. Thomas. 1967. "A Note on Evaluation," BSCS Newsletter. 30:2.

62. Heath, Robert W. 1964. New Curricula. New York: Harper and Row. 292 pp.

63. Hellmann, Robert A. 1965. "Evaluation in American School Biology Books from the Late Nineteenth Century until the 1930's," The American Biology Teacher. 27:779-780.

64. Howard, Eugene R. 1966. "Developing Student Responsibility for Learning," The Bulletin of the National Association of Secondary School Principals. 50(309):235-246.

65. Hurd, Paul Dehart. 1963. Science Teaching for a Changing World. A Scott, Foresman Monograph on Education. Chicago: Scott, Foresman and Company. 13 pp.

66. ————. 1962. "The New Curriculum Movement in Science," Science Teacher. 29:6-9.

67. ————. 1961. "Biological Education in American Secondary Schools 1890-1960," Biological Sciences Curriculum Study Bulletin No. 1. Washington, D. C.: American Institute of Biological Sciences. 263 pp.

68. Hutto, Thomas A. 1965. "A Need for Direction in the College Biology Curriculum," The American Biology Teacher. 27(1): 24-25.

69. Hutto, Thomas A. 1965. "The BSCS Program: Reaction from Students, Teachers, and Parents," School Science and Mathematics. 65(9):764-767.

70. Johnson, Donald M., and Stratton, Paul R. 1966. "Evaluation of Five Methods of Teaching Concepts," Journal of Educational Psychology. 57(1):48-53.

71. Kastrinos, William. 1965. "A Study of the Retention of Biological Facts by High School Biology Students," Science Education. 49:487-491.

72. Katona, George. 1940. Organizing and Memorizing. New York: Columbia University Press. 318 pp.

73. Klinckmann, Evelyn. 1961. "Preparation of Test Items and Tests for BSCS Biology," BSCS Newsletter. 10:8-11.

74. Klinge, Paul. 1965. "What's Ahead in Biology Education," The American Biology Teacher. 27:326.

75. Kochendorfer, Leonard H. 1967. "Classroom Practices of High School Biology Teachers Using Different Curriculum Materials," BSCS Newsletter. 30:25.

76. Lance, Mary Louise. 1964. "A Comparison of Gains in Achievement Made by Students of BSCS High School Biology and Students of a Conventional Course in Biology," Unpublished Ed.D. dissertation, University of Georgia. BSCS Newsletter. 30:21.

77. Lee, Addison E. 1963. "Experiments," The American Biology Teacher. 25:84.

78. ————. 1963. "Objectives," The American Biology Teacher. 25:484.

79. ————. 1960. "Block of Time Idea in Biological Laboratory Instruction," The American Biology Teacher. 22:135-139.

80. Lehman, David L. 1967. "A New Dimension in the Evaluation of BSCS," BSCS Newsletter. 30:21-25.

81. Lightner, Jerry P. 1964. "The BSCS and Advanced Biology," The American Biology Teacher. 26:338-340.

82. Lisonbee, Lorenzo and Fullerton, Bill J. 1964. "The Comparative Effect of BSCS and Traditional Biology on Student Achievement," School Science and Mathematics. 64(7):594-598.

83. Maberly, Norman C., and Margolin, Sandra Lee. 1965. "Biology Curriculum Patterns in Twenty-Nine High Schools," Science Education. 49:376-377.

84. Marshall, J. Stanley and Burkman, Ernest. 1966. Current Trends in Science Education. New York: The Center for Applied Research in Education, Inc. 115 pp.

85. Massey, Norman Bland. 1965. Patterns for the Teaching of Science. Toronto: The MacMillan Company of Canada Limited. 225 pp.

86. Matala, Dorothy. 1960. "The Biology Course - When to Teach It?" The American Biology Teacher. 22:270-271.

87. Mayer, William V. 1964. "The Impact of Testing on New Curricula," The American Biology Teacher. 26(8):585-588.

88. Metzner, Jerome. 1964. "The Gifted Student Program of the BSCS," The American Biology Teacher. 26:341-344.

89. Miller, George L. 1966. "The Teacher and Inquiry," Educational Leadership. 23(7):550-555.

90. Neal, Louise A. 1962. "Method of Scientific Inquiry," The Science Teacher. 29(5):53-55.

91. Nedelsky, Leo. 1965. Science Teaching and Testing. Chicago: Harcourt, Brace and World, Inc. 368 pp.

92. Noll, Victor H. 1939. The Teaching of Science in Elementary and Secondary Schools. New York: Longmans, Green & Co., 238 pp.

93. Novak, Alfred. 1963. "Scientific Inquiry in the Laboratory," The American Biology Teacher. 25:342-346.

94. Novak, Joseph D. 1965. "A Model for the Interpretation and Analysis of Concept Formation," Journal of Research in Science Teaching. 3:72-83.

95. Otto, James H., and Towle, Albert. 1965. Modern Biology. New York: Holt, Rinehart and Winston, Inc. 792 pp.

96. Pella, Milton O. 1966. "Concept Learning in Science," The Science Teacher. 33(9):31-34.

97. Peterson, Glen E. 1966. "Some Observations on Biology Teachers and Teaching," The American Biology Teacher. 28:173-175.

98. Robinson, James T. 1966. "Biology Methods Courses," The American Biology Teacher. 28:809-813.

99. Robinson, James T. 1965. "Science Teaching and the Nature of Science," Journal of Research in Science Teaching. 3:37-50.

100. Romey, William D. 1968. Inquiry Techniques for Teaching Science. Englewood Cliffs, New Jersey: Prentice-Hall, Inc. 342 pp.

101. Rutherford, F. James. 1964. "The Role of Inquiry in Science Teaching," Journal of Research in Science Teaching. 2:80-84.

102. School Management. 1964. "The New Science Curriculum: A Dissent." 8:76-82.

103. Schwab, Joseph J., and Brandwein, Paul. 1962. "The Teaching of Science." Harvard University Press, Cambridge. 152 pp.

104. Schwab, Joseph J. 1963. Biology Teachers' Handbook. New York: John Wiley and Sons, Inc. 585 pp.

105. Shell, Lester C. and Hawes-Davis, Denzil J. 1965. "Learning Biology at the College Freshman Level," The American Biology Teacher. 27(1):26-29.

106. Shulman, Lee S. 1965. "Seeking Styles and Individual Differences in Patterns of Inquiry," The School Review. 73(3):258-266.

107. Smith, Cameron. 1966. "Impact of the New National Science Curricula on the Established Science Program," The American School Board Journal. 152(2):14-16.

108. Suchman, J. Richard. 1966. "Inquiry: Inquiry in the Curriculum," The Instructor. 75(5):24+

109. ————. 1965. "Inquiry: In the Pursuit of Meaning," The Instructor. 75(1):32, 70.

110. ————. 1965. "Inquiry: The Motivation to Inquire," The Instructor. 75(2):26+

111. ————. 1965. "Inquiry: The Conditions for Inquiry," The Instructor. 75(3):30+

112. ————. 1965. "Inquiry: The Role of the Teacher," The Instructor. 75(4):26+

113. ————. 1962. The Elementary School Training Program in Scientific Inquiry. University of Illinois. 128 pp.

114. Sund, Robert B. and Trowbridge, Leslie W. 1967. Teaching Science by Inquiry. Columbus, Ohio: Charles E. Merrill Books, Inc. 357 pp.

115. The Psychological Corporation. 1967. "A Report on the Biological Sciences Curriculum Study End-of-Year Evaluation Program, 1964-1965." BSCS Newsletter. 30:3-7.

116. Thomas, Dempsey L. 1964. "A Suggested Teaching Schedule for Biological Science," The American Biology Teacher. 26:354-356.

117. Thurber, Walter A., and Collette, Alfred T. 1964. Teaching Science in Today's Secondary Schools, Second Edition. Boston: Allyn and Bacon, Inc. 703 pp.

118. Turner, George Cleveland. 1965. "An Analysis of Scientific Enquiry as Used in a BSCS Laboratory Program," Unpublished Ed.D. dissertation, Arizona State University.

119. Tyler, Ralph W. 1962. "Forces Redirecting Science Teaching," The Science Teacher. 29(6):22-25.

120. Van Deventer, W. C. 1963. "BSCS Biology," School Science and Mathematics. 63:89-94.

121. Voss, Burton E., and Brown, Stanley B. 1968. Biology as Inquiry: A Book of Teaching Methods. St. Louis: The C. V. Mosby Company, 239 pp.

122. Waetjen, Walter B. 1965. "Learning and Motivation: Implications for the Teaching of Science," The Science Teacher. 32(5): 22-26.

123. Wallace, Wimburn L. 1963. "The BSCS 1961-62 Evaluation Program - A Statistical Report," BSCS Newsletter. 19:22-24.

124. Weaver, Richard L. 1963. "BSCS Plus," The American Biology Teacher. 25:404.

125. Weinberg, Stanley L. 1966. Biology. Boston: Allyn and Bacon, Inc. 684 pp.

126. Weishar, William J., and Terry, Richard E. 1964. "Our First Year Under BSCS," The American Biology Teacher. 26:345-346.

127. Wong, Harry K. 1965. "Inquiry Training in a Biology and Research Program," School Science and Mathematics. 65(7):593-596.

128. Yager, Robert E. 1962. "Variation in the Success of Ninth and Tenth Year Students in General Biology," The American Biology Teacher. 24:569-572.

129. Yager, Robert E. 1962. "Retention of Principles of Biology by Ninth and Tenth Grade Students," The American Biology Teacher. 24:260-261.